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THE EFFECTS OF RCS JET FIRING ON THE ISOLATED ORBITER AND MATED COAST PHASES OF THE GLIDE RETURN TO LAUNCH SITE MANEUVER AT MACH NUMBER 6 (IA302B)

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April 1988

Final Report for Period 16 November - 12 December, 1987

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An updated Space Shuttle aerodynamic data base was obtained in Tunnel B for two phases of the Glide Return to Launch Site (GRTLS) abort maneuver. 1.25 percent scale models of the Space Shuttle Orbiter and External Tank were used to measure the effects of various combinations of Reaction Control System (RCS) jet thrusters at Mach number 6. The angle-of-attack range for the isolated orbiter was -10 to 15 deg at sideslip angles from -5 to 10 deg during Phase I of testing. The angle-of-attack range for the mated orbiter and external tank was -5 to 15 deg with sideslip angles of -2 to 5 deg during Phase II. The test was conducted at a unit Reynolds number of 0.75 million per foot.

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SAMPLE DATA

NOMENCLATURE

A	Reference area (orbiter model planform), 60.525 in.^{2}
AE	Nominal RCS jet exit area, 0.014698 in.^{2}
ALPHA	Angle of attack in body axes, deg
ALPI	Indicated sector pitch angle, deg
AN	Venturi flow meter throat area, 0.0486 in.^{2}
AR	RCS reference area, 0.0225 in.^{2}
AT	Nominal RCS jet throat area, 0.0011763 in.^{2}
B	Orbiter wing span, 11.709 in.
BASRU	Jet-off run used in calculating incremental coefficients
BC	Moment center of balance, in.
BETA	Side-slip angle in body axes, deg
C	Mean aerodynamic chord, 5.935 in.
CD	Venturi flow meter discharge coefficient
CLL	Rolling-moment coefficient, including thrust, body axes, [MX/(Q · A · L)]
CLLMC	Rolling-moment coefficient, including thrust, reduced about the mated coast reference center
CLLR	Rolling-moment coefficient, without thrust, body axes, [MXR/(Q · A · L)]
CLLRMC	Rolling-moment coefficient, without thrust, reduced about the mated coast reference center
CLM	Pitching-moment coefficient, including thrust, body axes. [MY/(Q · A · L)]
CLMMC	Pitching-moment coefficient, including thrust, reduced about the mated coast reference center
CLMR	Pitching-moment coefficient, without thrust, body axes, [MYR/(Q · A · L)]
CLMRMC	Pitching-moment coefficient, without thrust, reduced about the mated coast reference center

CLN	Yawing-moment coefficient, including thrust, body axes, [MZ/(Q · A · L)]
CLNMC	Yawing-moment coefficient, including thrust, reduced about the mated coast reference center
CLNR	Yawing-moment coefficient, without thrust, body axes. [MZR/(Q · A · L)]
CLNRMC	Yawing-moment coefficient, without thrust, reduced about the mated coast reference center
CN	Normal-force coefficient, including thrust, body axes. [FN/(Q · A)]
CNR	Normal-force coefficient, without thrust, body axes. [FNR/(Q · A)]
CODE	Model configuration code 1 - Isolated orbiter umbilical doors closed 2 - Isolated orbiter umbilical doors open 4 - Isolated orbiter body only 5 - Mated orbiter and external tank
CONFIG	RCS jet configuration code
CY	Side-force coefficient, including thrust, body axes. [FY/(Q · A)]
CYR	Side-force coefficient, without thrust, body axes. [FYR/(Q · A)]
DE	RCS thruster exit diameter, 0.1368 in.
DELMDOT	Delta between the measured venturi RCS mass flow rate and the theoretical RCS mass flow rate, [MDOT-WG], lbm/sec
DN	Venturi flow meter throat diameter, 0.2497 in.
DPV2	Venturi system differential pressure, psid
DT	RCS thruster throat diameter, 0.0387 in.
EZERO1	Voltage reading of hot film mass flow system with zero flow, volts
FN	Total normal-force on the model, thrust included, lbs
FN11	Total normal-force on the balance, thrust included, lbs
FNR	Normal-force on the model, without thrust, lbs.

FY	Total side-force on the model, thrust included, lbs
FY11	Total side-force on the balance, thrust included, lbs
FYR	Side-force on the balance, without thrust, lbs.
G	Nominal gravitational acceleration constant, 32.174 ft/sec^2
ICLLR	Incremental rolling-moment coefficient [Jet on Run - BASRU] (typ.)
ICLMR	Incremental pitching-moment coefficient
ICLNR	Incremental yawing-moment coefficient
ICNR	Incremental normal-force coefficient
ICYR	Incremental side-force coefficient
K1	Calibration constant for model chamber pressure PC1
K2	Calibration constant for model chamber pressure PC2
KM1	Rockwell-supplied mass flow calibration factor for forward RCS jets, $\frac{lbm \sqrt{°R}}{sec \quad psia}$
KM2	Rockwell-supplied mass flow calibration factor for aft RCS jets, $\frac{lbm \sqrt{°R}}{sec \quad psia}$
KTHALD	Rockwell-supplied RCS group thrust calibration factor for aft left side, down-firing, lbf/psia
KTHALS	Rockwell-supplied RCS group thrust calibration factor for aft left side, side-firing, lbf/psia
KTHALU	Rockwell-supplied RCS group thrust calibration factor for aft left side, up-firing, lbf/psia
KTHARD	Rockwell-supplied RCS group thrust calibration factor for aft right side, down-firing, lbf/psia
KTHARS	Rockwell-supplied RCS group thrust calibration factor for aft right side, side-firing, lbf/psia
KTHARU	Rockwell-supplied RCS group thrust calibration factor for aft right side, up-firing, lbf/psia
KTHFLD	Rockwell-supplied RCS group thrust calibration factor for forward left side, down-firing, lbf/psia

KTHFLS	Rockwell-supplied RCS group thrust calibration factor for forward left side, side-firing, lbf/psia
KTHFRD	Rockwell-supplied RCS group thrust calibration factor for forward right side, down-firing, lbf/psia
KTHFRS	Rockwell-supplied RCS group thrust calibration factor for forward right side, side-firing, lbf/psia
LH2	Abbreviation for liquid hydrogen
LOX	Abbreviation for liquid oxygen
M	Free-stream Mach number
MDOT	Auxiliary air flow rate, lbm/sec
MDOTP	Intermediate venturi mass flow calculation parameter
MPREV	Previous mass flow rate measured for a particular RCS configuration and RCS chamber pressure, lbm/sec
MRC	Moment reference center of orbiter
MRXXXA/T	Actual or theoretical momentum ratio for the nominal nozzle geometry, XXX
MSYS	Denoted mass flow system used; 1 - Hotfilm, 2 - Venturi
MU	Free-stream flow viscosity, $lb_f\text{-sec/ft}^2$
MX	Total rolling-moment on the model, thrust included, body axes, in.-lb
MX11	Total rolling-moment on the balance, thrust included, in.-lb
MXR	Rolling-moment on the model, without thrust body axes, in.-lb
MY	Total pitching-moment on the model, thrust included, body axes, in.-lb
MY11	Total pitching-moment on the balance, thrust included, in-lb
MYR	Pitching-moment on the model, without thrust, body axes, in.-lb

MZ	Total yawing-moment on the model, thrust included, body axes, in.-lb
MZ11	Total yawing-moment on the balance, thrust included, in.-lb
MZR	Yawing-moment on the model, without thrust, body axes, in.-lb
NALD	Number of RCS jets for aft left group, down firing
NALS	Number of RCS jets for aft left group, side firing
NALU	Number of RCS jets for aft left group, up firing
NARD	Number of RCS jets for aft right group, down firing
NARS	Number of RCS jets for aft right group, side firing
NARU	Number of RCS jets for aft right group, up firing
NFLD	Number of RCS jets for forward left group, down firing
NFLS	Number of RCS jets for forward left group, side firing
NFRD	Number of RCS jets for forward right group, down firing
NFRS	Number of RCS jets for forward right group, side firing
NXXX	Number of RCS jets for nozzle geometry, XXX
P	Free-stream static pressure, psia
PB01	Model base pressure, psia
PB02	Model base pressure, psia
PC	Average calculated model chamber pressure, psia
PC1	Calculated model forward chamber pressure, psia
PC1A	Measured model forward chamber pressure, psia
PC2	Calculated model aft chamber pressure, psia
PC2A	Measured model aft chamber pressure, psia
PHII	Indicated sector roll angle, deg

PHIM	Intermediate venturi mass flow calculation parameter
PN	Data point number
PREF	Transducer reference pressure, psia
PS1	Sting air supply line static pressure, psia
PSWB	Tunnel test section bottom sidewall pressure, psia
PSWT	Tunnel test section top sidewall pressure, psia
PT	Free-stream total pressure, psia
PTANK1	Tunnel injection tank static pressure, psia
PTANK2	Tunnel injection tank static pressure, psia
PTS	Sting air supply line total pressure, psia
PTV2	Auxiliary air total pressure upstream of venturi flow meter, psia
Q	Free-stream dynamic pressure, psia
RE	Free-stream unit Reynolds number, ft^{-1}
RED	Intermediate venturi mass flow calculation parameter
REF LENGTHS, L	Reference lengths used to calculate the pitching-, yawing-, and rolling-moment coefficient, 16.129 in.
RHO	Free-stream air density, lbm/ft^3
RUN	Data run number
S	Model reference area (used for data reduction on isolated and mated configurations), 60.525 $in.^2$
T	Free-stream static temperature, °R
TALDA/T	Actual or theoretical thrust, aft left down RCS jets, lb
TALSA/T	Actual or theoretical thrust, aft left side RCS jets, lb
TALUA/T	Actual or theoretical thrust, aft left up RCS jets, lb

TARDA/T	Actual or theoretical thrust, aft right down RCS jets, lb
TARSA/T	Actual or theoretical thrust, aft right side RCS jets, lb
TARUA/T	Actual or theoretical thrust, aft right up RCS jets, lb
TBA	Measured balance aft temperature, °F
TBF	Measured balance forward temperature, °F
TC	Measured temperature in model air supply chambers, °R
TDP	Tunnel free-stream dew point temperature, °F
TFLDA/T	Actual or theoretical thrust, forward left down RCS jets, lb
TFLSA/T	Actual or theoretical thrust forward left side RCS jets, lb
TFRDA/T	Actual or theoretical thrust forward right down RCS jets, lb
TFRSA/T	Actual or theoretical thrust forward right side RCS jets, lb
TGFLOW	Target flow meter mass flow rate, lbm/sec
TMODEL	Measured temperature on sting at base of model, °F
TOLER	Allowed tolerance in mass flow setting, lbm/sec
TSTING	Measured temperature of mass flow at a point inside the tank, °F
TT	Tunnel stilling chamber temperature, °R
TTV2	Total temperature of mass flow measured upstream of venturi flow meter, °R
TXXXA/T	Actual or theoretical thrust for the nominal nozzle geometry, XXX
WG	Auxiliary air flow rate calculated using Rockwell-supplied discharge coefficients, lbm/sec

1.0 INTRODUCTION

The work reported herein was performed by the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC) under Program Element 921E01, Control Number 9E01, at the request of NASA Johnson Space Center, Houston, Texas. The NASA project manager was Mr. O. B. Kanipe, and the Rockwell International representative was Mr. A. C. Mansfield. The DOFA project manager was Mr. J. H. McComb. The results were obtained by Calspan Corporation, operating contractor of the Aerospace Flight Dynamics testing effort at the AEDC, AFSC, Arnold Air Force Base, Tennessee. The test was performed in the von Karman Gas Dynamics Facility (VKF), Hypersonic Wind Tunnel B, during the period of November 16 through December 12, 1987, under AEDC Project Number CI85VB (Calspan Number V41B-38).

The primary test objective was to obtain an updated Space Shuttle aerodynamic data base for two phases of the Glide Return to Launch Site (GRTLS) abort trajectory to support the digital autopilot command matrix. Existing models of the orbiter and external tank were used to measure the effects of various combinations of RCS thrusters and thruster momentum ratios at Mach number 6. The angle of attack for the isolated orbiter ranged from -10 to 15 deg at sideslip angles from -5 to 10 deg. A separate installation was used to achieve a -5 to 15 deg angle of attack range and sideslip angles from -2 to 5 deg for the mated orbiter and external tank configuration. The test was conducted at a unit Reynolds number of 0.75 million per foot.

Inquiries to obtain copies of the test data should be directed to NASA/JSC, ED 3, Houston, TX 77058. A microfiche record of the final data has been retained at AEDC.

2.0 APPARATUS

2.1 TEST FACILITY

Tunnel B (Fig. 1) is a closed-circuit hypersonic wind tunnel with a 50 in. diameter test section. Two axisymmetric contoured nozzles are available to provide Mach numbers of 6 and 8. The tunnel may be operated continuously over a range of pressures from 20 to 300 psia at Mach number 6, and 50 to 900 psia at Mach number 8, with air supplied by the VKF main compressor plant. Stagnation temperatures sufficient to avoid air liquefaction in the test section (up to 1350°R) are obtained through the use of a natural gas fired combustion heater. The entire tunnel (throat, nozzle, test section, and diffuser) is cooled by integral, external water jackets. The tunnel is equipped with a model injection system which allows removal of the model from the test section while the tunnel remains in operation. A description of the tunnel may be found in Ref. 1.

2.2 TEST ARTICLE

The Space Shuttle Vehicle 102 Orbiter and Light Weight External Tank (ET), designated Model 70-OT (Fig. 2), were supplied by Rockwell International. Both the tank and orbiter were 1.25 percent scale models primarily constructed of Armco 17-4 steel.

The orbiter model was a blended wing body with a double delta wing planform and full span elevons with an interpanel gap between the inboard and outboard panels. A single centerline vertical tail with rudder and/or speedbrake capability was mounted between the two OMS pods, and a single body flap was fitted on the lower trailing edge of the fuselage. All control surfaces were maintained at zero deflection during the test. Nozzle recesses and all other significant protuberances and penetrations were simulated on the model. Model reference dimensions are denoted in Table 1.

The orbiter model had the capability of simulating the firing of the RCS jet thrusters by directing high pressure gas through pre-calibrated flow-through nozzles. The model RCS system consisted of three removable RCS nozzle "blocks", one located in the nose and one located in each of the two OMS pods. Each block within the OMS pods contained nine nozzles which simulated the thrusters. The nose block contained eight nozzles. Of the thirty-four RCS thrusters simulated on the model, eight were inactive. The RCS nozzle locations are shown in Fig. 3, and the RCS thruster coordinates are included in Table 2.

All thrusters in a nozzle block were fed from a common chamber. The chamber for each block was connected to the auxiliary mass flow System through the model support sting and load balance. Chamber pressures in both the aft and forward blocks were correlated with the static and pitot pressure in the sting air supply line. A single thruster could be operated separately or in combination with any of the other thrusters by removing plugs from specific holes in the nozzle blocks. The combinations of RCS thrusters are shown in Table 3. Schematics of the RCS configurations are given in Table 4.

The External Tank model includes the protuberances of the light weight ET configuration. The ET model incorporated the biconic nose spike. (Ref. 3)

The isolated orbiter was tested with the umbilical doors open (Fig. 4) and closed to simulate the two phases of the GRTLS abort trajectory. The orbiter is connected to the ET through the umbilical doors; therefore, the isolated configuration with the umbilical doors open simulates the portion of the GRTLS maneuver immediately following the orbiter and ET separation. The isolated orbiter with umbilical doors closed simulates the post-separation orbiter recovery. In addition, the mated orbiter and ET configuration were tested. The isolated orbiter and the mated orbiter and ET installation are shown in Figs. 5 and 6, respectively.

2.3 TEST INSTRUMENTATION

The instrumentation, recording devices, and calibration methods used for all measured parameters are listed in Table 5. In Tunnel B, stilling chamber pressure is measured with a 200 or 1000 psid transducer referenced to a near vacuum; the stilling chamber temperature is measured with Chromel-Alumel® thermocouples.

2.3.1 Pressure and Mass Flow Instrumentation

Pressures in the sting air supply line were measured with two 2000 psi Bell and Howell pressure transducers calibrated for the range of 200 to 1200 psia. During the jet calibration phase of the test, pressures in the model air supply chambers were measured with two additional 2000 psi Bell and Howell transducers calibrated for the same range. The Tunnel B Standard Pressure System (SPS) was used to measure the ambient pressure on the model during the jet calibrations. The SPS uses 15 psid transducers with ranges of 0.15, 1.5, and 15 psia and is referenced to a near vacuum.

The auxiliary mass flow system was used to supply air to the model during jet calibrations and tests. A hot-film anemometer package was used for flow rates lower than 0.05 lbm/sec and supply pressures less than 900 psia during the calibration procedures and for a few runs. A long-radius venturi package was used for higher flow rates and pressures.

A 2 micron filter and a 10 micron filter were placed in series in the mass flow line leading directly to the orbiter model (Fig. 7). The mass flow system was cleaned, and the air was sampled. The amount of solids in the flow was not enough to obstruct the flow through the nozzles.

2.3.2 Model Force Instrumentation

Model forces and moments were measured with a five-component, flow-through, strain-gage balance (designated SS05) which was supplied by NASA Langley Research Center and was calibrated by AEDC. The balance was temperature compensated from 80 to 180°F by NASA Langley Research Center.

2.3.3 Optical

Model flow field shadowgraph/Schlieren photographs were obtained during the test on all configurations at selected model attitudes. The photographs were obtained with a single-pass optical flow visualization system through two 17.25 in. diameter test section windows.

3.0 TEST DESCRIPTION

3.1 TEST CONDITIONS

The nominal test condition for the test is given below:

M	PT, psia	TT, °R	Q, psia	P, psia	RE, 10^6/ft	V, ft/sec	T, °R
5.96	40.3	850.7	0.662	0.027	0.75	2994	105

A test run summary showing all configurations is presented in Table 7b.

3.2 TEST PROCEDURES

3.2.1 General

In the continuous-flow Wind Tunnel B, the model is mounted on a sting support mechanism in an installation tank directly underneath the tunnel test section. When closed, the fairing doors cover the opening to the tank, except for a slot around the pitch sector, and a safety door seals the tunnel from the tank area. After the model is prepared for a data run, the personnel access door to the installation tank is closed, the tank is vented to the tunnel flow, the safety and fairing doors are opened, the model is injected into the airstream, and the fairing doors are closed. After the data are obtained, the sequence is reversed; the model is retracted into the tank, and the tank is vented to atmosphere to allow access to the model in preparation for the next run. The sequence is repeated for each configuration change.

3.2.2 Data Acquisition

Model attitude positioning and data recording were accomplished with the point-pause and continuous sweep modes of operation, using the VKF Model Attitude Control System (MACS). Model pitch and roll requirements were entered into the controlling computer prior to the test. Model positioning and data recording operations were performed automatically during the test by selecting the list of desired model attitudes and initiating the system.

Point-pause data were obtained for selected values of ALPHA and BETA after a 1.0 sec delay for stabilization. Continuous sweep data were obtained with a pitch rate of 1.0 deg/sec. A data sample was recorded every 0.0208 sec, and a sliding Kaiser-Bessel digital filter was applied to 16 samples to produce a data point every 0.33 deg in pitch and 1.00 deg in roll. The filtered data were then interpolated to obtain data at the requested model attitudes.

Prior to the force testing phase, a calibration was made to correlate PC1A and PC2A (the model air supply chamber pressures) with PTS (the pitot pressure in the sting air supply line) for several RCS jet configurations. These data were extrapolated to obtain correlations for the remaining jet configurations. The PC1A and PC2A pressure tubes were then disconnected from the model to eliminate

interference with the force balance. A run summary of the pressure chamber calibrations is included in Table 7a.

Thrust calibrations were performed by reducing the pressure in the model installation tank to approximately 0.5 psia and obtaining force data at several mass flow rates. The reduced tank pressure was required to ensure that the flow from each RCS jet was fully expanded. To eliminate jet impingement, a sting-mounted shield was placed at the aft end of the model, and the model wing and bodyflap were removed. The calibrations provided a correlation between PTS and the thrust measured by the five balance components. A thrust calibration was performed for eighteen elemental thrust build-ups (Table 6). Each RCS configuration was comprised of various combinations of the build-ups.

During the actual air-on testing phase, the model configuration, RCS nozzle configuration, and mass flow rate were set in the tank before the model was injected into the tunnel flow. Following the run, the model remained in the tunnel test section, a new mass flow rate was set, and data were obtained. For some configurations an initial run was made at a zero mass flow rate. Jet-off runs demonstrated the repeatability of the force and moment balance and also was used to compute the difference between jet-on and jet-off force data to examine interference effects.

3.3 DATA REDUCTION

3.3.1 Forces and Moments

Static force data were reduced to coefficient form using the digitally filtered data points. The data were corrected for first and second order balance interactions and for the effects of RCS air supply pressure on the balance. The aerodynamic coefficients were corrected for model tare weight and balance sting deflections. Model attitude and tunnel stilling chamber pressure were also calculated from digitally filtered values.

Model aerodynamic force and moment coefficients were presented in the body axis system. The reference area was the model planform of 60.525 $in.^2$. Moment coefficients were referenced to a point corresponding to 66 percent of the orbiter body length and also to a point corresponding to the Mated Coast reference center located at 65 percent of the orbiter body length (Fig. 8). The model orbiter length of 16.129 in. was used to normalize pitching, yawing and rolling moments.

The body axes coefficients were corrected for thrust effects using the following equations:

$$CNR = CN - KT1 \cdot PTS / (Q \cdot S)$$

$$CLMR = CLM - KT2 \cdot PTS / (Q \cdot S \cdot L1)$$

$$CYR = CY - KT3 \cdot PTS / (Q \cdot S)$$

$$CLNR = CLN - KT4 \cdot PTS / (Q \cdot S \cdot L2)$$

$$CLLR = CLL - KT5 \cdot PTS / (Q \cdot S \cdot L3)$$

where KT1-5 were determined during the thrust calibration described in section 3.2.2 and are listed in Table 8.

The interference effect coefficients were calculated using the equations:

$$ICNR = CNR_{jet\text{-}on\ run} - CNR_{BASRU}$$

$$ICLMR = CLMR_{jet\text{-}on\ run} - CLMR_{BASRU}$$

$$ICYR = CYR_{jet\text{-}on\ run} - CYR_{BASRU}$$

$$ICLNR = CLNR_{jet\text{-}on\ run} - CLNR_{BASRU}$$

$$ICLLR = CLLR_{jet\text{-}on\ run} - CLLR_{BASRU}.$$

3.3.2 Pressures

The sting pressures, PTS and PS1, were measured parameters. The model chamber pressures, PC1A and PC2A, also were measured during the calibration phase. For the remainder of the test, the model chamber pressures were calculated using the calibration constants, i.e.:

$$PC1 = K1 . PTS$$

$$PC2 = K2 . PTS$$

where K1=K2 = $1 - 2.176 \cdot 10^{-5}$ (Σ nozzles)^2.

3.3.3 Temperatures

TC and TTV2 were measured temperatures of the air supplied by the auxiliary mass flow system.

3.3.4 Flow Rates

The equations used for the venturi flow rate data reduction are:

$$P2PA = 1.0 - DPV2/PTV2$$

$$PHIM = \frac{\left(P2PA^{1.42857} / 0.28571\right) \cdot \left(1.0 - P2PA^{0.28571}\right)}{\left(1.0 - 0.000397 \cdot P2PA^{1.42857}\right)^{0.5}}$$

$$MDOTP = \frac{1.09822 \cdot PHIM \cdot PTV2 \cdot AN}{(TTV2)^{0.5}}$$

$$MU = 2.89 \cdot 10^{-9} \cdot TTV2^{0.7778}$$

$$RED = \frac{MDOTP \cdot 48}{MU \cdot \pi \cdot DN \cdot G}$$

$$CD = 1.0 - 2.39 / RED^{0.4}$$

$$MDOT = CD \cdot MDOTP .$$

The theoretical flow rate calculation was made using discharge coefficients provided by Rockwell, which resulted in the equation:

$$WG = (KM1 \cdot PC1 + KM2 \cdot PC2) / TC^{0.5} .$$

The values of KM1 and KM2 were derived by summing the mass flow calibration factors for each thruster in the RCS configuration (Table 9). KM1 represented the forward thrusters while KM2 represented the aft thrusters.

In addition to the venturi flow meter, a target flow meter was installed in the mass flow line inside the tunnel installation tank. The target flow meter was primarily used to identify leaks in the mass flow system by highlighting inconsistencies in the venturi readings. Mass flow impinging on a "target" in the instrument stresses a strain-gage which is calibrated to accurately determine the mass flow rate.

3.3.5 Thrust and Momentum Ratios

Four groups of jets were designated for the RCS system: FLS, forward left side; FRS, forward right side; ALS, aft left side; and ARS, aft right side. For each group, theoretical and "actual" thrusts and momentum ratios were calculated. The theoretical thrusts were calculated using the nominal RCS jet geometry which resulted in the equation:

$$TxxxT = Nxxx \cdot (0.0019554 \cdot PCx - 0.0147 \cdot P)$$

where xxx designates the jet group, and PCx was PC1 for the forward groups and PC2 for the aft groups. P represents the average of two measurements of the tunnel injection tank static pressure (PTANK1 and PTANK2).

The "actual" thrusts were computed using discharge coefficients provided by Rockwell. The resulting equation was:

$$TxxxA = KTHxxx \cdot PCx \cdot Nxxx \cdot P \cdot AE$$

with xxx, PCx and P representing the same convention as above. The KTHxxx values were derived by summing the RCS nozzle thrust calibration factors for each jet group (Table 9).

Similiarly, the theoretical momentum ratios were determined using the nominal jet geometry. The resulting equation was:

$$MRxxxT = (0.0022345 \cdot PCx) / Q .$$

The "actual" momentum ratio for each group was then determined using the equation:

$$MRxxxA = (TxxxA \cdot MRxxxT) / TxxxT .$$

3.4 MEASUREMENT UNCERTAINTIES

In general, instrumentation calibration and data uncertainty measurements were made using methods presented in Ref. 2. Measurement uncertainty (U) is a combination of bias and precision errors defined as:

$$U = \pm\ (B + t_{95}S)$$

where B is the bias limit, S is the standard deviation, and t_{95} is the 95th percentile point for the two-tailed Student's "t" Distribution (95-percent confidence interval), which equals 2 for degrees of freedom greater than 30.

Estimates of measured data uncertainties for this test are given in Table 5a. With the exception of the force and moment balances, data uncertainties are determined from in-place calibrations through the data recording system and the data reduction program. Prior to the test, static loads in each plane and combined loads were applied to the balance to simulate the range of loads and center-of-pressure locations anticipated during the test. This simulated loading was performed with and without an internal balance pressure of 1000 psia. In addition a posttest balance loading (which correlated with the pretest loading) was performed to ensure the posttest integrity of the balance. Measurement errors are based on differences between applied loads and corresponding values calculated from the balance equations used in the data reduction. Additional precautions taken to protect data quality included not removing the model from the balance during the test and acquiring frequent repeat runs. Repeatability remained within the measurement errors.

Propagation of the bias and precision errors of measured data through the calculated data was made in accordance with Ref. 2 and the results are given in Table 5b. Uncertainties for the calculated data are presented for the maximum value of each parameter measured.

4.0 DATA PACKAGE PRESENTATION

Force and moment data, mass flow data, and test conditions were reduced to tabular form for presentation as a Data Package. Examples of the basic tabulations are shown in the Sample Data.

Missing run numbers or deleted data points indicated bad data or nonexistent runs. For runs during which the balance design loads were exceeded, the affected data point(s) are denoted by an * in the left margin of the tabulated data.

All photographic data, including model installation and shadowgraph/schlieren photographs, were sent to the user under separate cover.

REFERENCES

1. Test Facilities Handbook (Twelfth Edition). "von Karman Gas Dynamics Facility, Vol. 3," Arnold Engineering Development Center, March 1984.

2. Abernethy, R.B. et. al. and Thompson, J.W. "Handbook Uncertainty in Gas Turbine Measurements." AEDC-TR-73-5 (AD755356), February 1973.

3. Collette, J. G. R. and Marshall, B. A., "Pretest Information for the Space Shuttle Reaction Control System/ET Separation Aerodynamics Tests IA-302A,B in the Arnold Engineering Development Center VKF Wind Tunnel "B" Using Model 70-OT," STS87-0079, April 1987.

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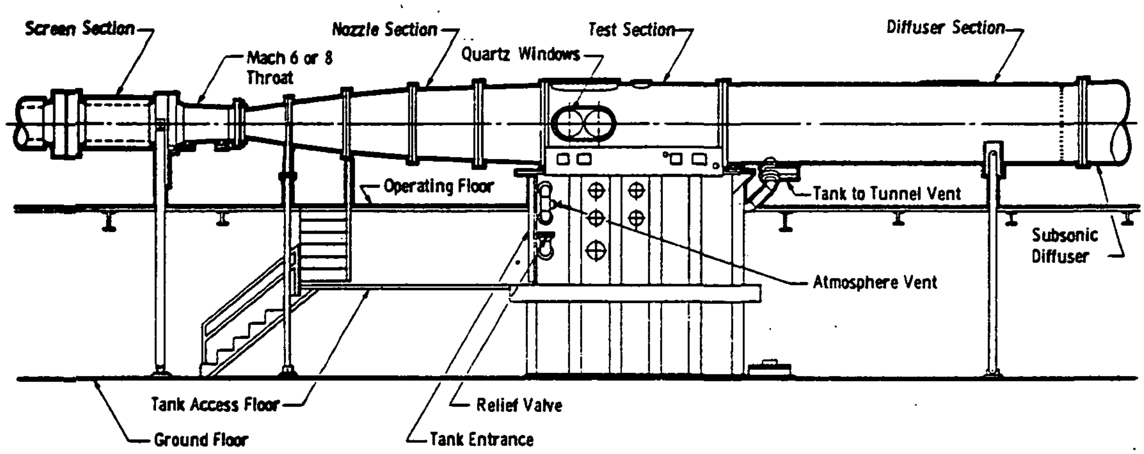
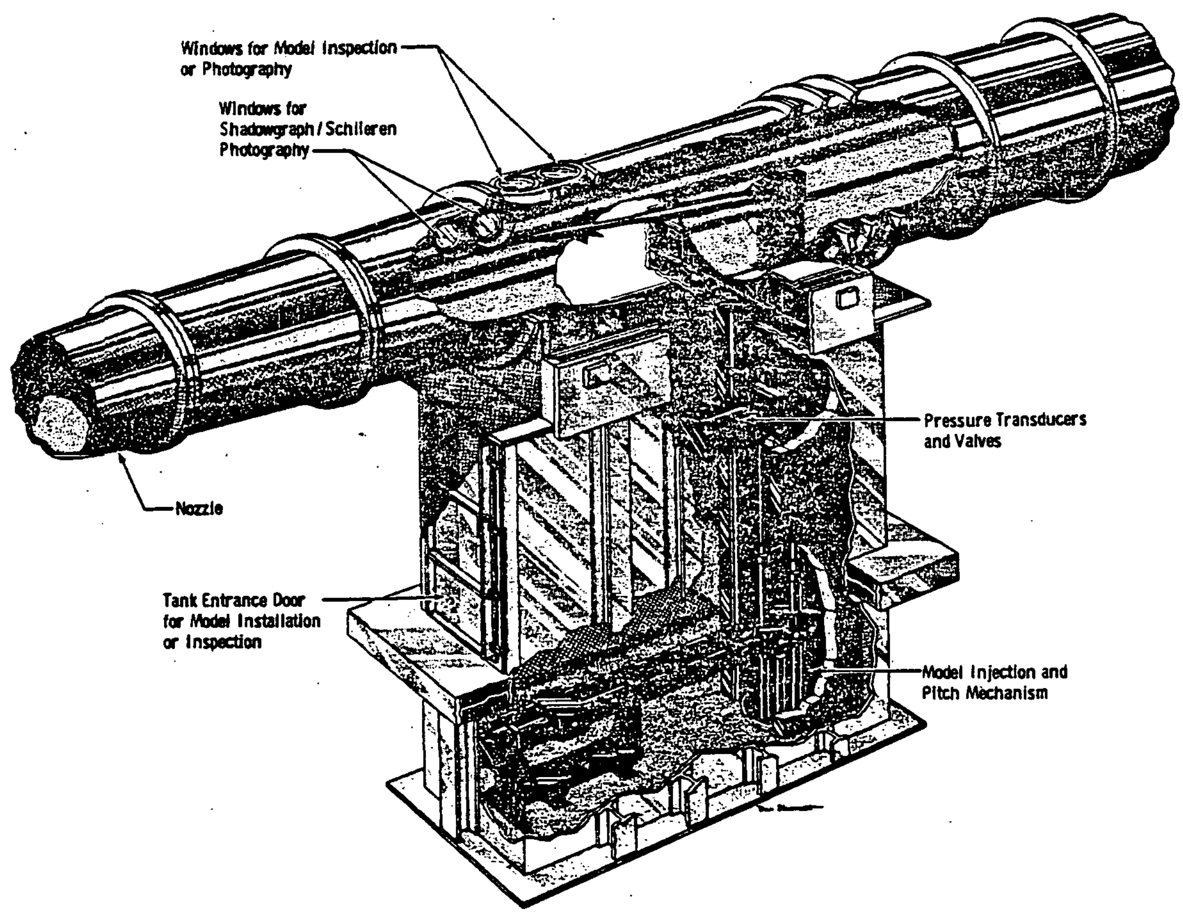


a. Tunnel assembly



b. Tunnel test section

FIGURE 1. HYPERSONIC WIND TUNNEL B

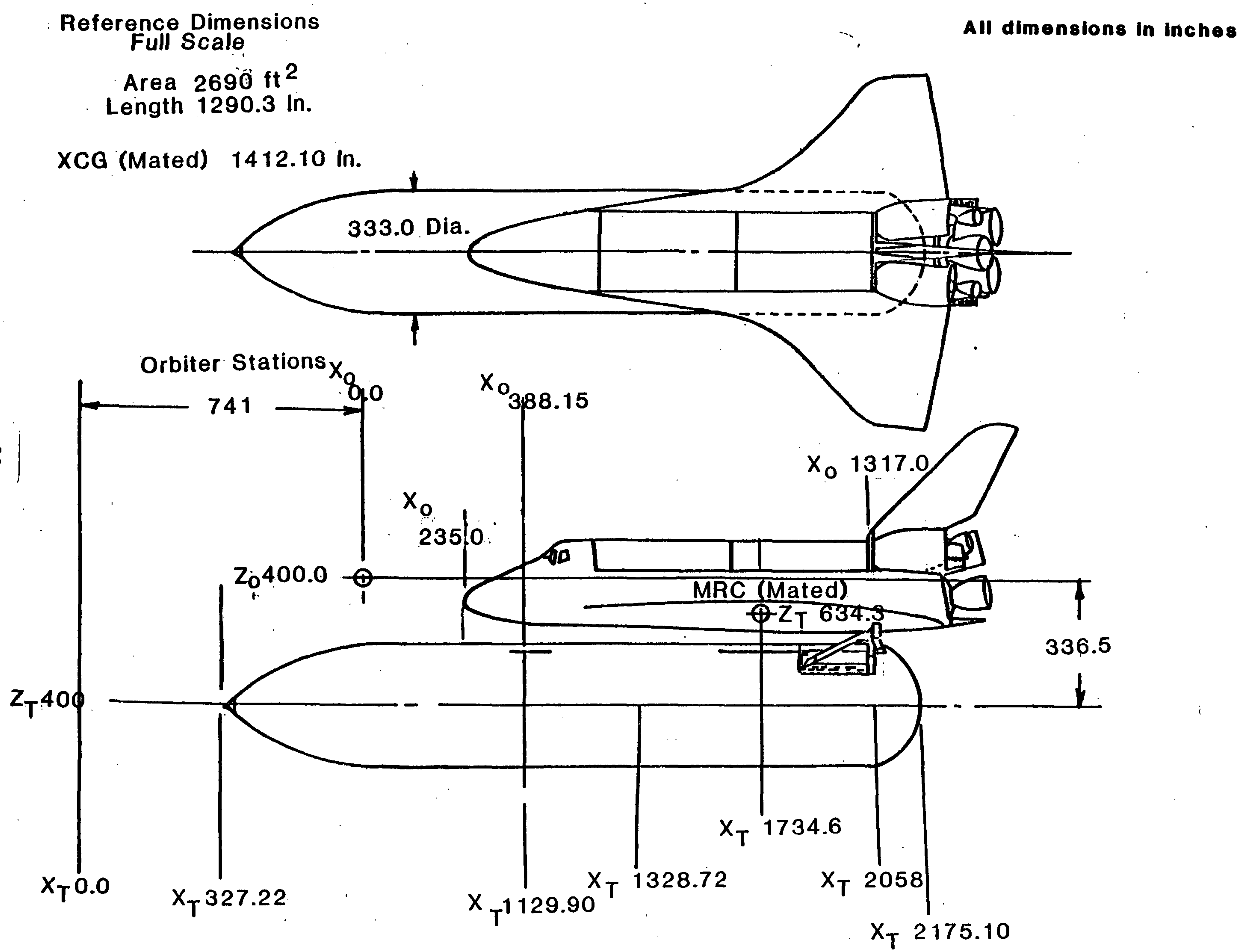


FIGURE 2. SHUTTLE ORBITER AND EXTERNAL TANK MODEL

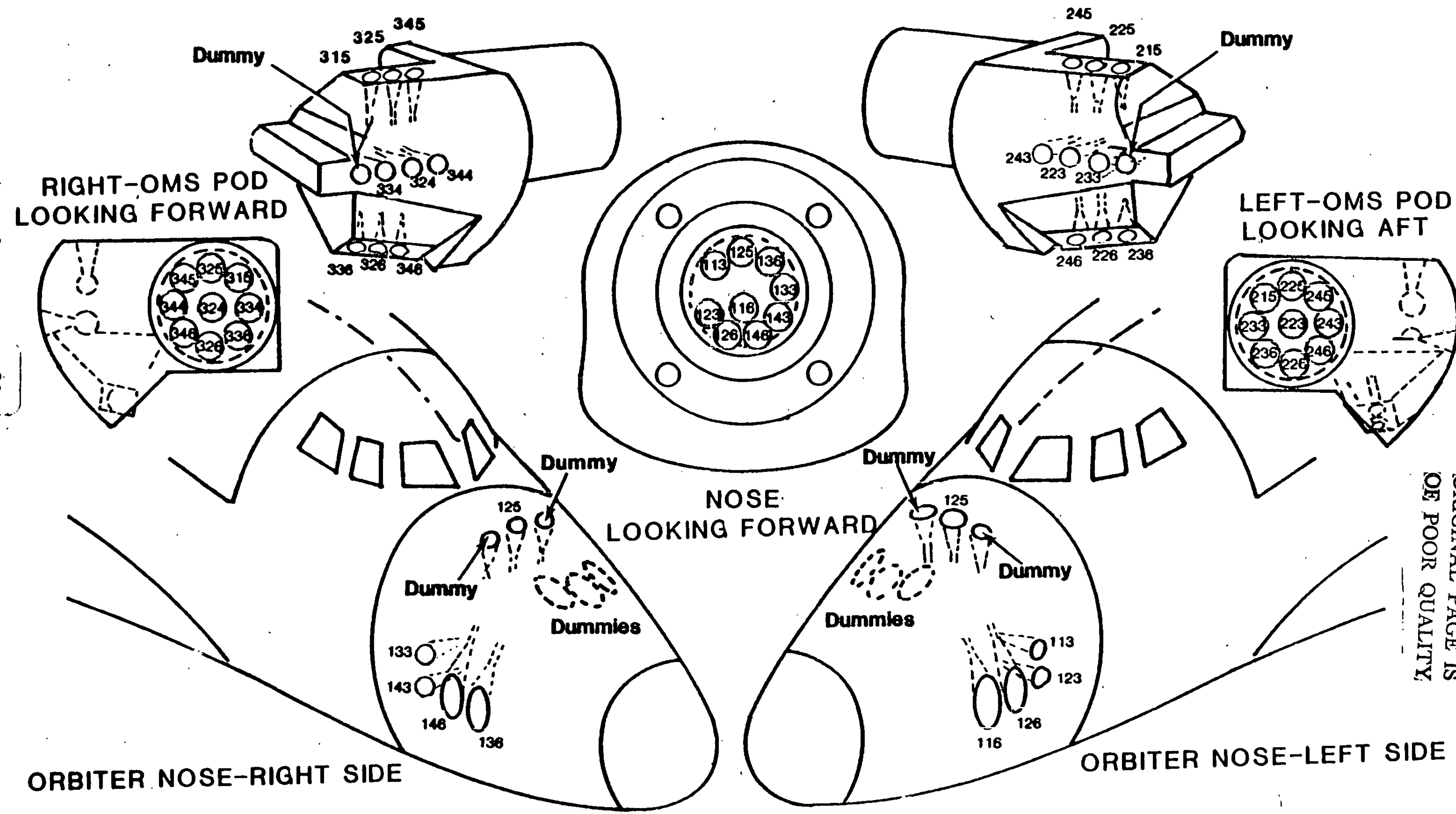


FIGURE 3. RCS NOZZLE LOCATIONS

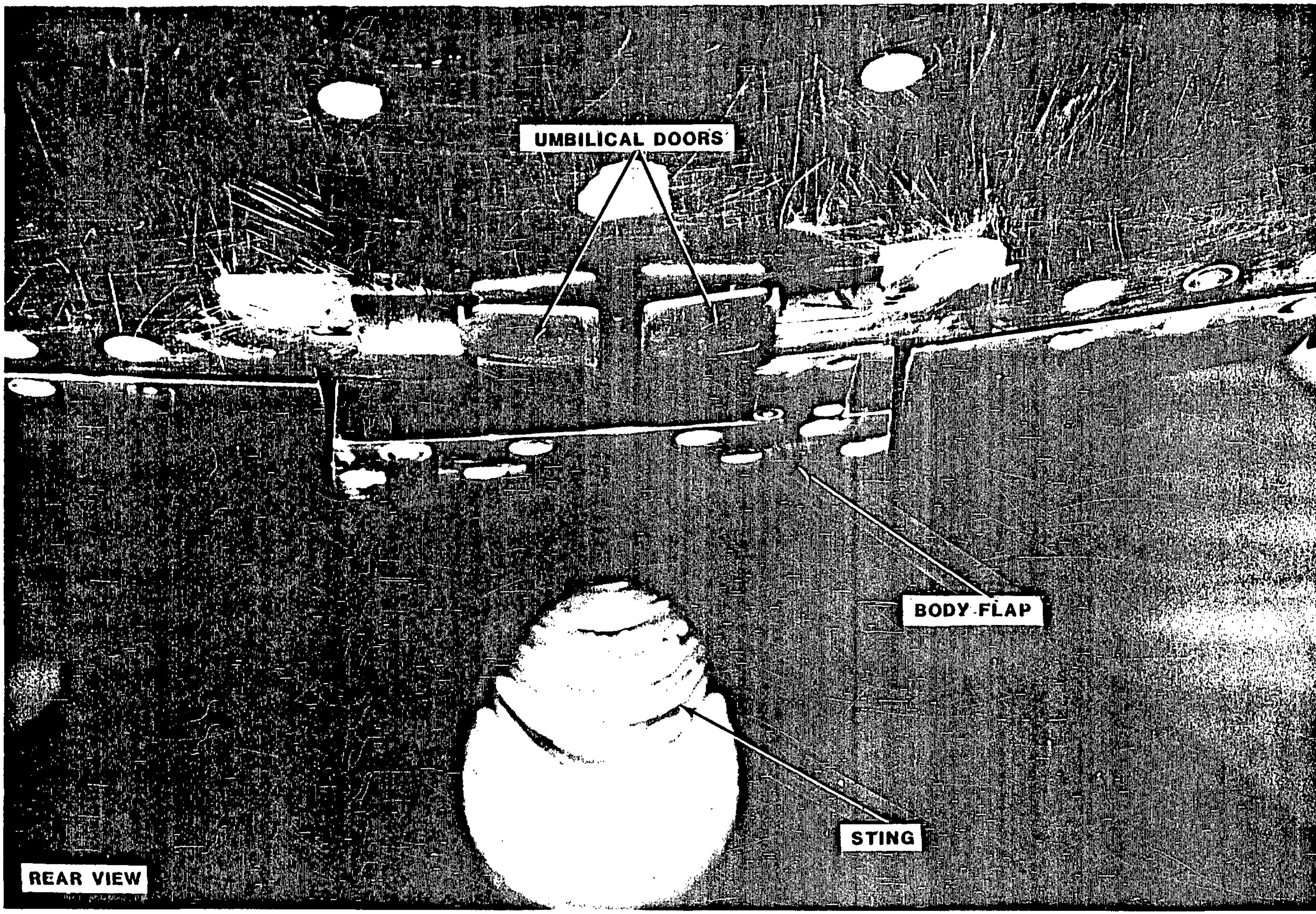


FIGURE 4. ISOLATED ORBITER WITH UMBILICAL DOORS OPEN

20611 C185 (12/11/87) NASA/RI SHUTTLE MATED COAST TEST

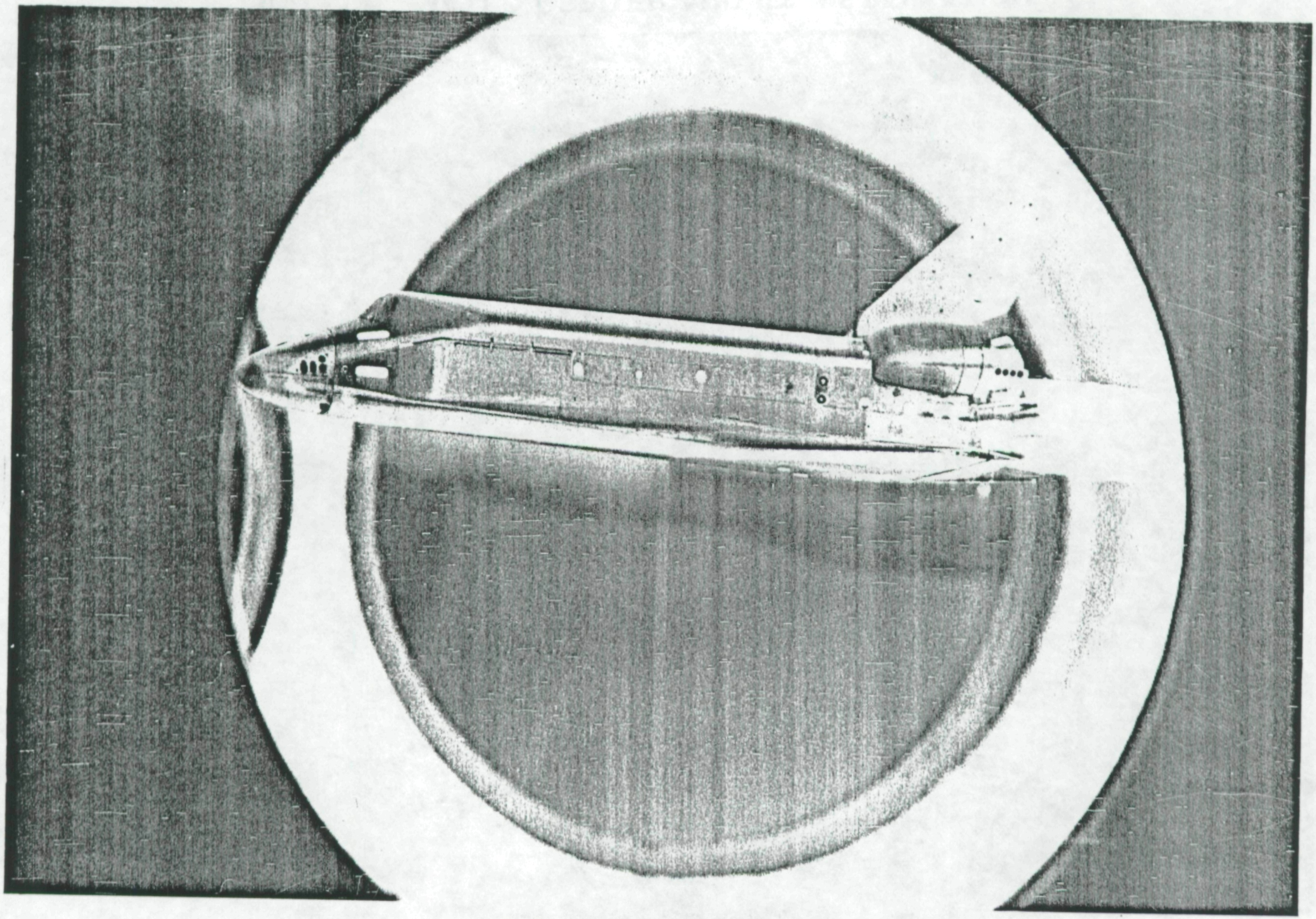


FIGURE 5. ISOLATED ORBITER INSTALLATION

20327 C185VB (12/08/87) INSTALLATION

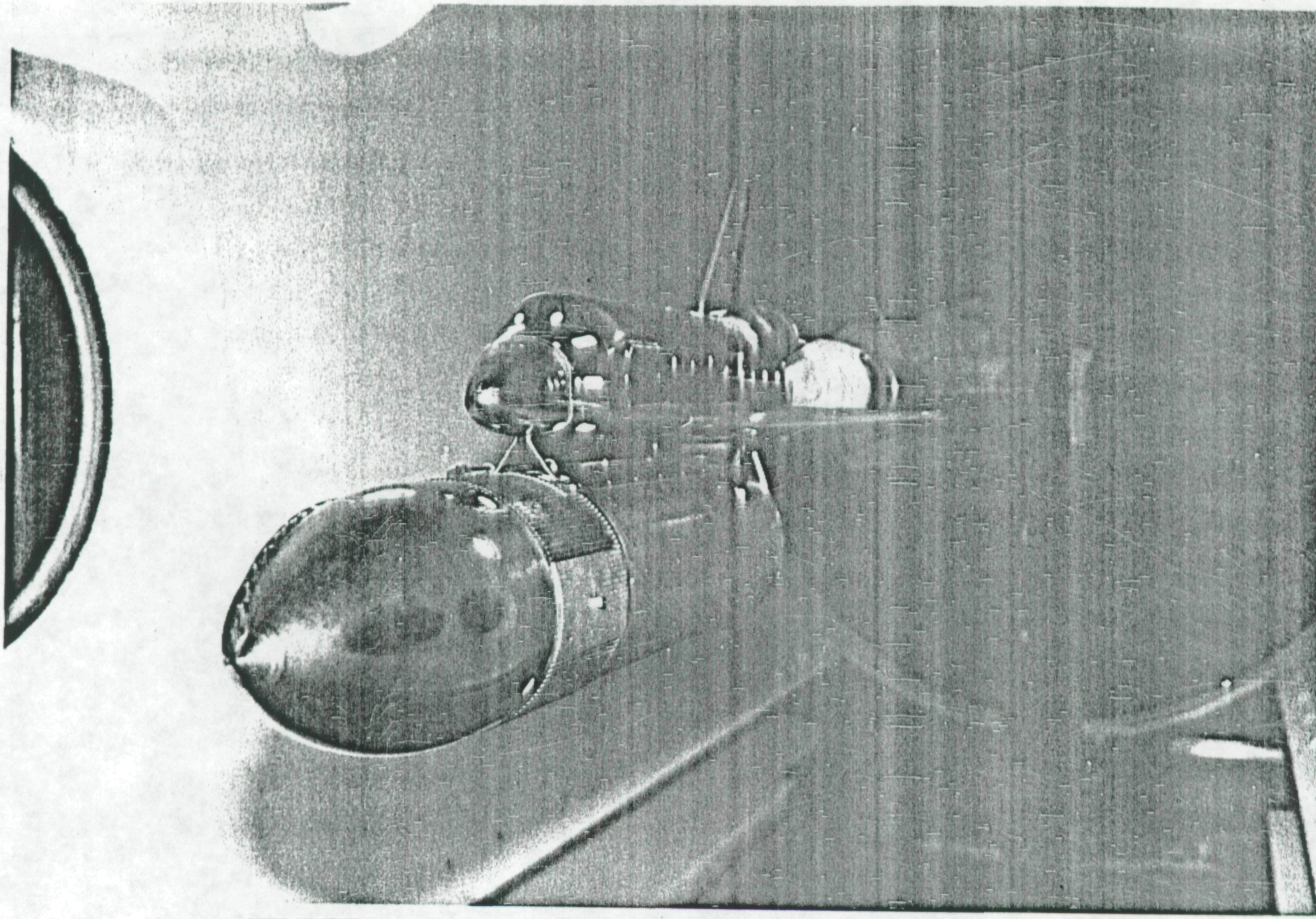


FIGURE 6. MATED ORBITER AND ET INSTALLATION

20622 C185 (12/11/87) NASA/RI SHUTTLE MATED COAST TEST

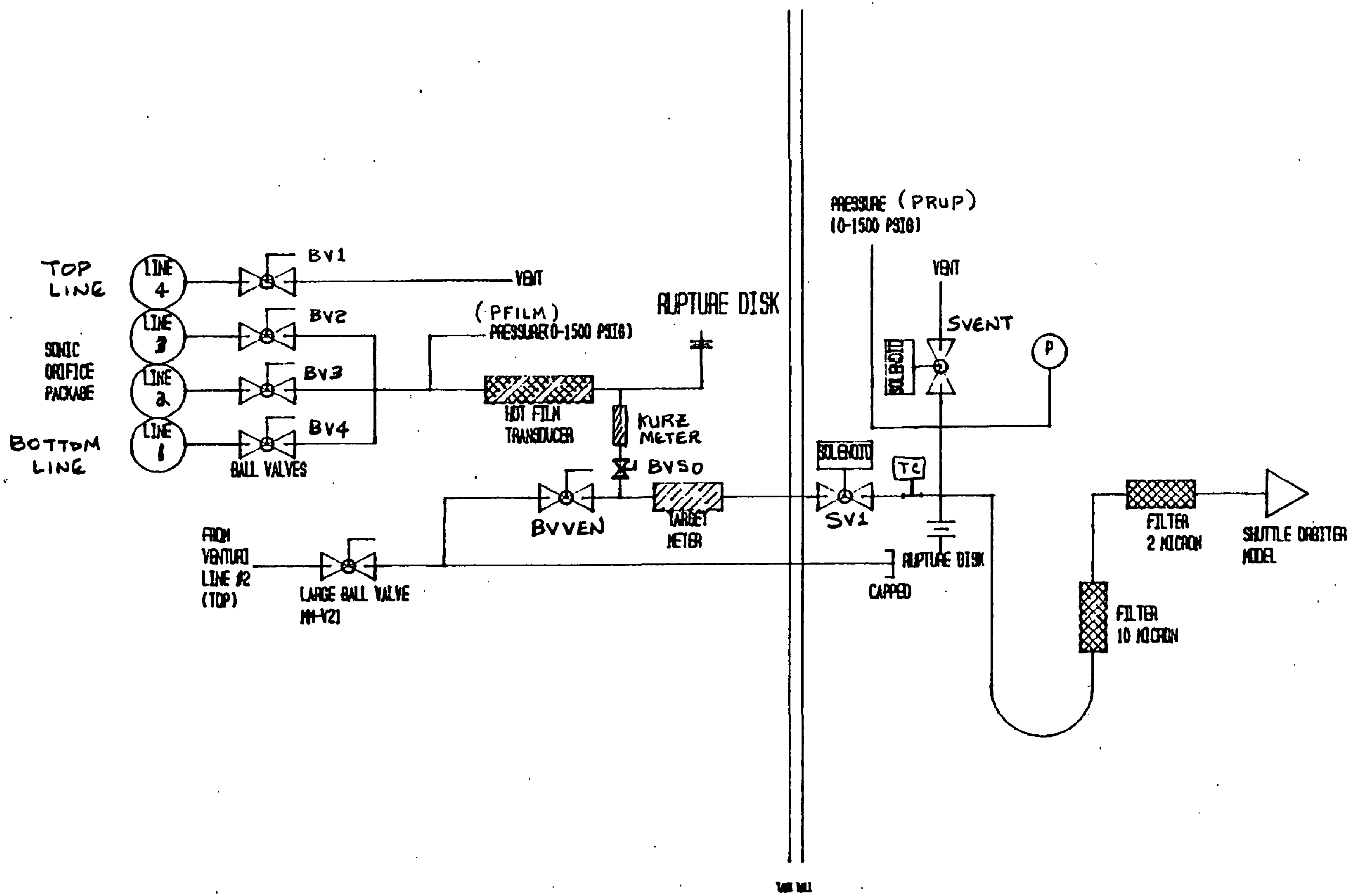


FIGURE 7. MASS FLOW SYSTEM

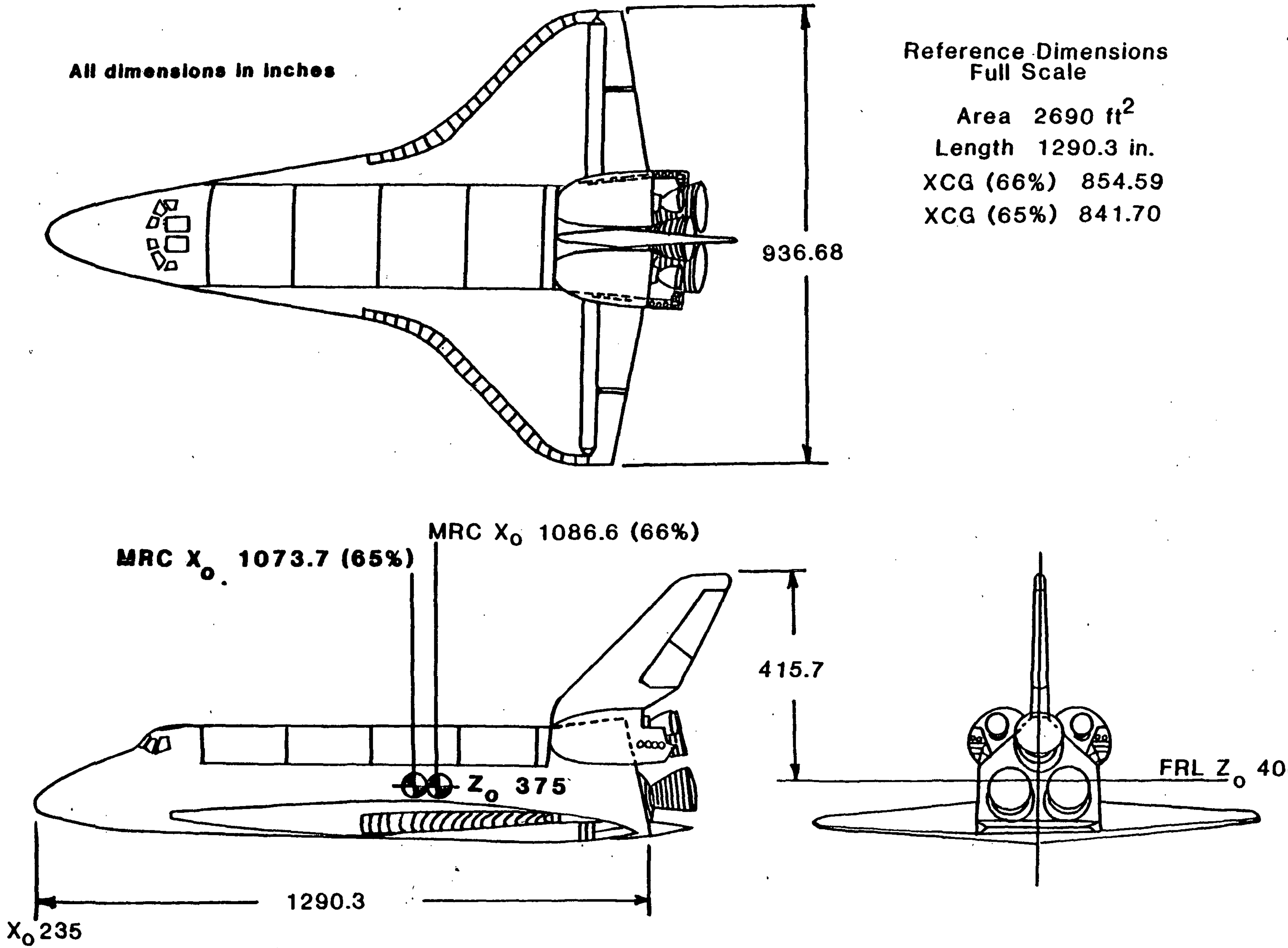


FIGURE 8. ISOLATED ORBITER

TABLE 1. MODEL REFERENCE DIMENSIONS

Symbol	Full Scale	Model
AE		0.14698 in^2
AT		0.0011763 in^2
AR		0.0225 in^2
B	78.057 ft.	11.709 in.
BC		xo = 13.459 in. yo = 0 in. zo = 4.75 in.
C		5.935 in.
DE		0.1368 in.
DT		0.0387 in.
LB	1290.3 in.	16.129 in.
MRC	xo = 1089.6 in. yo = 0 in. zo = 375.0 in	xo = 13.620 in. yo = 0 in. zo = 4.688 in.
S	2690 ft^2	0.4203 ft^2
XCG (66%)	854.59 in.	10.645 in.
XCG (65%)	841.70 in.	10.484 in.

Orbiter nose is at xo = 235 full-scale equivalent to xo = 2.9375 model scale.
XCG is measured from model nose.

TABLE 2. RCS THRUSTER COORDINATES

THRUSTER NO.	MODEL SCALE (in.) X_o	Y_o	Z_o
113	4.535	-0.869	4.670
116	4.200	-0.793	4.458
123	4.560	-0.894	4.494
126	4.375	-0.845	4.469
133	4.535	0.869	4.670
136	4.200	0.793	4.458
143	4.560	0.894	4.494
146	4.375	0.845	4.469
215	19.275	-1.650	6.232
223	19.113	-1.869	5.738
225	19.113	-1.650	6.232
226	19.144	-1.441	5.352
233	19.275	-1.869	5.738
236	19.307	-1.430	5.384
243	18.950	-1.869	5.738
245	18.950	-1.650	6.232
246	18.982	-1.449	5.319
315	19.275	1.650	6.232
324	19.113	1.869	5.738
325	19.113	1.650	6.232
326	19.144	1.441	5.352
334	19.275	1.869	5.738
336	19.307	1.430	5.384
344	18.950	1.869	5.738
345	18.950	1.650	6.232
346	18.982	1.449	5.319

Note: Thruster reference point is the intersection of the thruster axis and the model surface.

TABLE 3. RCS THRUSTER CONFIGURATIONS

NOZZLE CONFIG.	FORWARD THRUSTERS						AFT LEFT THRUSTERS									AFT RIGHT THRUSTERS								
	S 123	S 113	D 116	D 126	D 136	D 146	U 245	U 225	U 215	S 243	S 223	S 233	D 246	D 226	D 236	U 345	U 325	U 315	S 344	S 324	S 334	D 346	D 326	D 336
1													X	X		X								
2													X	X	X	X	X							
3													X	X	X							X	X	X
4			X	X	X	X							X	X	X							X	X	X
5			X	X	X	X							X	X	X	X	X							
6			X	X	X	X							X	X		X								
7,49			X	X	X	X																		
8	X		X	X	X	X													X	X				
9	X		X	X	X	X							X	X	X				X	X		X	X	X
10	X		X	X	X	X							X	X	X	X	X		X	X				
11	X		X	X	X	X							X	X		X			X	X				
12	X		X	X	X	X	X												X	X		X	X	
13	X		X	X	X	X	X	X											X	X		X	X	X
14	X						X	X											X	X		X	X	X
15	X						X												X	X		X	X	
16	X												X	X	X	X			X	X				

X–THRUSTER FIRING, U–UP FIRING, S–SIDE FIRING, D–DOWN FIRING

TABLE 3. (CONTINUED)

NOZZLE CONFIG.	FORWARD THRUSTERS						AFT LEFT THRUSTERS									AFT RIGHT THRUSTERS								
	S 123	S 113	D 116	D 126	D 136	D 146	U 245	U 225	U 215	S 243	S 223	S 233	D 246	D 226	D 236	U 345	U 325	U 315	S 344	S 324	S 334	D 346	D 326	D 336
17	X												X	X	X	X	X		X	X				
18	X												X	X	X				X	X		X	X	X
19													X	X	X				X	X	X	X	X	X
20													X	X	X				X	X	X			
21													X	X	X									
22										X	X	X	X	X	X									
23			X	X	X	X				X	X	X	X	X	X									
24			X	X	X	X							X	X	X									
25			X	X	X	X							X	X	X				X	X	X			
26			X	X	X	X													X	X	X			
27			X	X	X	X							X	X	X				X	X	X	X	X	X
28							X						X	X	X	X								
29													X	X	X							X	X	X
30	X	X																	X	X	X			
31	X	X																	X					
32	X	X											X	X	X				X			X	X	X

X–THRUSTER FIRING, U–UP FIRING, S–SIDE FIRING, D–DOWN FIRING

TABLE 3. (CONTINUED)

NOZZLE CONFIG.	FORWARD THRUSTERS						AFT LEFT THRUSTERS									AFT RIGHT THRUSTERS								
	S 123	S 113	D 116	D 126	D 136	D 146	U 245	U 225	U 215	S 243	S 223	S 233	D 246	D 226	D 236	U 345	U 325	U 315	S 344	S 324	S 334	D 346	D 326	D 336
33	X	X											X	X	X				X	X	X	X	X	X
34	X	X					X						X	X	X	X			X	X	X			
35	X	X					X						X	X	X	X			X					
36	X	X					X									X			X			X	X	X
37	X	X					X									X			X	X	X	X	X	X
38	X	X	X	X	X	X	X	X	X							X	X	X	X			X	X	X
39	X	X	X	X	X	X	X	X	X							X	X	X	X	X	X	X	X	X
40	X	X	X	X	X	X	X	X	X							X	X	X	X	X	X			
41	X	X	X	X	X	X	X	X	X							X	X	X	X					
42	X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X					
43	X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X			
44			X	X	X	X	X	X	X				X	X	X	X	X	X						
45			X	X	X	X	X	X	X							X	X	X						
50	X	X	X	X	X	X																		
51	X	X																						

X–THRUSTER FIRING, U–UP FIRING, S–SIDE FIRING, D–DOWN FIRING

TABLE 3. (CONCLUDED)

NOZZLE CONFIG.	FORWARD THRUSTERS						AFT LEFT THRUSTERS									AFT RIGHT THRUSTERS								
	S 123	S 113	D 116	D 126	D 136	D 146	U 245	U 225	U 215	S 243	S 223	S 233	D 246	D 226	D 236	U 345	U 325	U 315	S 344	S 324	S 334	D 348	D 328	D 338
60			X		X								X	X	X							X	X	X
61	X																				X			
140										X	X													

X–THRUSTER FIRING, U–UP FIRING, S–SIDE FIRING, D–DOWN FIRING

TABLE 4. RCS THRUSTER CONFIGURATION SCHEMATICS

CONF. NO.	M_R NOZ.	RCS JET DIAGRAMS	CONF. NO.	M_R NOZ.	RCS JET DIAGRAMS
1	—/246		19	—/246	
2	—/246		20	—/246	
3	—/246		21	—/246	
4	116/246		22	—/246	
5	116/246		23	116/246	
6	116/246		24	116/246	
7/49	116/—		25	116/246	
8	116/344		26	116/344	
9	116/246		27	116/246	
10	116/246		60	116/246	
11	116/246		61	123/344	
12	116/346		140	—/243	
13	116/346				
14	123/346				
15	123/346				
16	123/246				
17	123/246				FWD AFT
18	123/246				LOOKING FORWARD

TABLE 4. (CONCLUDED)

CONF. NO	M_R NOZ.	RCS JET DIAGRAMS
28	—/246	
29	—/246	
30	123/344	
31	123/344	
32	123/246	
33	123/246	
34	123/246	
35	123/246	
36	123/346	
37	123/346	
38	116/346	
39	116/346	
40	116/245	
41	116/245	
42	116/246	
43	116/246	
44	116/246	
45	116/245	
50	—	
51	—	
52	—	PLUME OFF

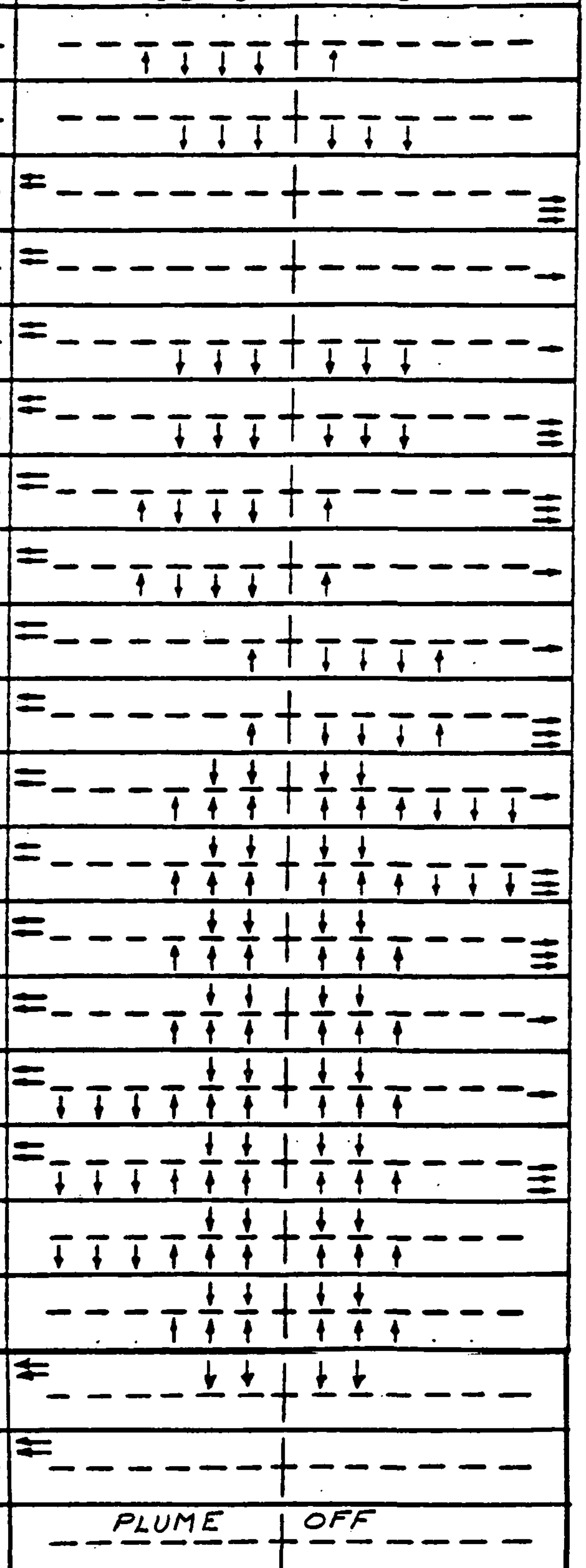


TABLE 5. ESTIMATED UNCERTAINTIES

a. Measured Parameters

Parameter Designation	Steady-State Estimated Measurement*							Range	Type of Measuring Device	Type of Recording Device	Method of System Calibration
	Precision Index + (S)			Bias + (B)		Uncertainty ±(B + t95S)					
	Percent of Reading	Unit of Measurement	Degree of Freedom	Percent of Reading	Unit of Measurement	Percent of Reading	Unit of Measurement				
PT, psia		0.1	> 30		0.1		0.3	<900	Piezoelectric Digiquartz Pressure Transducer	Digital Data Acquisition System analog-to-digital converter	In-place application of multiple pressure levels measured with a pressure measuring device calibrated in the standards laboratory
PTS, PS1, PC1A, PC2A, psia		± 0.005 ± .4 psid	> 30		± 1.2 psid		±2.0	<2000	Bell and Howell force balance pressure transducer	Digital Data Acquisition System analog-to-digital converter	In-place application of multiple pressure levels measured with a pressure measuring device calibrated in the standards laboratory
PFILM, PTV2, psia		0.22	> 30		1.5		1.9	<2000	Setra variable capacitance pressure transducer	Digital Data Acquisition System analog-to-digital converter	In-place application of multiple pressure levels measured with a pressure measuring device calibrated in the standards laboratory
DPV2, psid		0.006	> 30		0.20		0.22	50	Setra variable capacitance pressure transducer	Digital Data Acquisition System analog-to-digital converter	In-place application of multiple pressure levels measured with a pressure measuring device calibrated in the standards laboratory
TT, TIV2, TFILM, TSTING, F		1.0	> 30		2.0		4.0	32 - 530 F	Chromel-Alumel thermocouple	Digital thermometer microprocessor	Thermocouple verification of NBS conformity/ voltage substitution calibration

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*Reference: Abernethy, R. B. et al and Thompson, J. W. "Handbook Uncertainty in Gas Turbine Measurements." AEDC-TSR-73-5, February 1973.

TABLE 5. (CONTINUED)

a. Measured Parameters (Concluded)

Parameter Designation	Steady-State Estimated Measurement* — Precision Index + (S): Percent of Reading	Precision Index + (S): Unit of Measurement	Precision Index + (S): Degree of Freedom	Bias + (B): Percent of Reading	Bias + (B): Unit of Measurement	Uncertainty ±(B + t95S): Percent of Reading	Uncertainty ±(B + t95S): Unit of Measurement	Range	Type of Measuring Device	Type of Recording Device	Method of System Calibration
MDOT (Hotfilm) Standard ft³/min		0.02	2	5		±(5 + 8.6x10⁻³)		.03 - 16	TSI Series 1352 hotfilm anemometer mass flow transducer	Digital Data Acquisition sysyem analog-to-digital converter	Comparison of output rotometer maintained by PMEL.
ALPI, deg		0.025	> 30		0+		0.05	±15	Potentiometer	Digital Data Acquisition sysyem analog-to-digital converter	Heidenhain rotary encoder ROD700 Resolution: 0.0006 deg Overall accuracy: 0.001 deg
PHII, deg		0.15	> 30		0+		0.30	±180			
Normal Force, lbs		0.09	> 30		0.16		0.34	±400	NASA SS05 Strain gage balance	Digital data acquisition sysyem analog-to-digital converter	Hanging precision weights and calculating ΔR's with pressure applied (calibration lab)
Pitching Moment, in-lbs		0.27	> 30		0,05		0.59	±400			
Side Force, lbs		0.09	> 30		0.00		0.18	± 60			
Yawing Moment, in-lbs		0.10	> 30		0.06		0.26	± 48			
Rolling Moment, in-lbs		0.12	> 30		0.08		0.32	± 40			

*Reference: Abernethy, R. B. et al and Thompson, J. W. "Handbook Uncertainty in Gas Turbine Measurements." AEDC-TSR-73-5, February 1973.

TABLE 5. (CONTINUED)

b. Calculated Parameters

Parameter Designation	Steady-State Estimated Measurement*						Nominal Value
	Precision Index (S)		Bias (B)		Uncertainty ±(B + t95S)		
	Percent of Reading	Unit of Measurement	Percent of Reading	Unit of Measurement	Percent of Reading	Unit of Measurement	
CN		0.003		0.004		0.01	0.596
CLM		0.0008		0.0004		0.002	0.169
CY		0.0025		0.0007		0.006	-0.292
CLN		0.0003		0.0002		0.001	0.079
CLL		0.0002		0.0001		0.0006	-0.025
CN		0.002		0.004		0.008	SEE NOTE 1
CLM		0.0004		0.00008		0.0009	SEE NOTE 1
CY		0.002		0.0		0.004	SEE NOTE 1
CLN		0.0001		0.00009		0.0003	SEE NOTE 1
CLL		0.0002		0.0001		0.0005	SEE NOTE 1
ALPHA, deg		0.025		0.0003		0.05	18.0
BETA, deg		0.014		0.0001		0.05	10.29

1. Calculation made without Q uncertainty.

*Reference: Abernethy, R.B. et al and Thompson, J.W. "Handbook Uncertainty in Gas Turbine Measurements." AEDC-TR-73-5, February 1973.

TABLE 5. (CONCLUDED)

b. Calculated Parameters (concluded)

Parameter Designation	Steady-State Estimated Measurement*						Nominal Value
	Precision Index (S)		Bias (B)		Uncertainty $\pm(B + t95S)$		
	Percent of Reading	Unit of Measurement	Percent of Reading	Unit of Measurement	Percent of Reading	Unit of Measurement	
M	0.08		0.0		0.17		5.96
RE, ft^{-1}	0.37		0.43		1.18		0.75 E+6
Q, psia	0.43		0.25		1.11		0.66
P, psia	0.57		0.25		1.40		0.27
T, R	0.19		0.24		0.61		105
V, ft/sec	0.06		0.12		0.24		2994

*Reference: Abernethy, R.B. et al and Thompson, J.W. "Handbook Uncertainty in Gas Turbine Measurements." AEDC-TR-73-5, February 1973.

TABLE 6. THRUST TARE CONFIGURATION BUILD-UPS

NOZZLE CONFIG.	FORWARD THRUSTERS						AFT LEFT THRUSTERS									AFT RIGHT THRUSTERS								
	S 123	S 113	D 116	D 126	D 136	D 146	U 245	U 225	U 215	S 243	S 223	S 233	D 246	D 226	D 236	U 345	U 325	U 315	S 344	S 324	S 334	D 348	D 328	D 338
101			X		X																			
102				X		X																		
104													X	X										
105																						X	X	
106													X	X	X									
107																						X	X	X
111	X																							
112	X	X																						
113										X	X	X												
114																			X					
115																			X	X				
116																			X	X	X			
132							X																	
133							X	X																
134							X	X	X															
135																X								
136																X	X							
137																X	X	X						

X—THRUSTER FIRING, U—UP FIRING, S—SIDE FIRING, D—DOWN FIRING

TABLE 7. TEST RUN SUMMARY

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a. Calibration runs

RCS Config.	Chamber Pressure Calibrations	Thrust Calibrations
3	8300, 8308	
4	8301	
7	8302	
9	8710, 8711	
43		8800, 8801
50	8306	
60		8806
61	8304	8807
101		8375, 8626, 8627, 8646, 8647
102		8363, 8393, 8628, 8629, 8648, 8649
104		8504, 8642, 8643
105		8390, 8612, 8613
106		8362, 8640, 8641
107		8361, 8394, 8610, 8611
111		8378, 8630, 8631
112		8379, 8632, 8633
113		8386, 8644, 8645
114		8382, 8614, 8615
115		8383, 8616, 8617
116		8385, 8618, 8619
132		8505, 8634, 8635
133		8506, 8636, 8637
134		8509, 8638, 8639
135		8507, 8620, 8621
136		8508, 8622, 8623
137		8510, 8624, 8625

TABLE 7. (CONTINUED)

b. Test Matrix Runs

UMBILICAL DOORS	RCS CONFIG	BETA	PC (psia) 0
CLOSED	N/A	0	1-5, 34
			54, 55, 80
			103-105
			199 222
			222, 247
			250, 251
			268, 317
			507, 508
		-5	6, 35, 106
			252, 504
		+5	7, 36, 107
			253, 505
		+10	8, 108, 254
			506

TABLE 7. (CONTINUED)

b. Test Matrix Runs (continued)

UMBILICAL DOORS	RCS CONFIG	BETA	PC (psia) 0
OPEN	N/A	0	548, 549
			565, 585
			686
		− 2	550, 566
		+ 2	551, 567
		+ 5	552, 568

MATED

UMBILICAL DOORS	RCS CONFIG	BETA	PC (psia) 0
OPEN	N/A	0	537, 538
			853
		− 2	819, 820
			831, 832
		+ 2	833
		+ 5	843

TABLE 7. (CONTINUED)

b. Test Matrix Runs (continued)

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			515	770	1030	
CLOSED	1	0	305	309	313	5
		-5	306	310	314	504
		+5	307	311	315	505
		+10	308	312	316	506
	2	0	318	322	326	5
		-5	319	323	327	504
		+5	320	324	328	505
		+10	321	325	329	506
	3	0	22	26	30	5
		-5	23	27	31	6
		+5	24	28	32	107
		+10	25	29	33	108
	4	0	109	113	117	5
			444	448	452	5
		-5	110	114	118	6
			445	449	453	504
		+5	111	115	119	107
			446	450	454	505
		+10	112	116	120	108
			447	451	455	506

TABLE 7. (CONTINUED)

b. Test Matrix Runs (continued)

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA) 515	770	1030	BASRU
CLOSED	5	0	396	400	404	5
		-5	397	401	405	504
		+5	398	402	406	505
		+10	399	403	407	506
	6	0	408	412	416	5
		-5	409	413	417	504
		+5	410	414	418	505
		+10	411	415	419	506
	7	0	121	125	129	5
		↓	492	496	500	5
		-5	122	126	130	6
		↓	493	497	501	504
		+5	123	127	131	107
		↓	494	498	502	505
		+10	124	128	132	108
		↓	495	499	503	506
	8	0	354	358	362	5
		-5	355	359	363	252
		+5	356	360	364	107
		+10	357	361	365	108

TABLE 7. (CONTINUED)

b. Test Matrix Runs (continued)

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			515	770	1030	
CLOSED	9	0	10	14	9	5
			—	—	18	
			56	60	64	
			—	—	93	
			255	259	263	
			—	—	267	
		-5	11	15	19	6
			57	61	65	6
			256	260	264	252
		+5	12	16	*20	7 / *107
			58	62	66	107
			257	261	265	107
		+10	13	17	*21	8 / *108
			59	63	67	108
			258	262	266	108
	10	0	68	72	76	5
			509	513	517	
			—	521	—	
		-5	69	73	77	6
			510	514	518	252
			—	522	—	252

TABLE 7. (CONTINUED)

b. Test Matrix Runs (continued)

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			515	770	1030	
CLOSED	10	+5	70	74	78	107
↓	↓	↓	511	515	519	↓
			—	523	—	
		+10	71	75	79	108
		↓	512	516	520	↓
			—	524	—	
	11	0	81	85	89	5
	↓	↓	525	529	533	↓
		-5	82	86	90	6
		↓	526	530	534	252
		+5	83	87	91	107
		↓	527	531	535	↓
		+10	84	88	92	108
		↓	528	532	536	↓
	12	0	94	98	—	5
	↓	↓	366	370	374	↓
			—	—	395	
		-5	95	99	—	6
		↓	367	371	375	252
			392	393	394	↓

TABLE 7. (CONTINUED)

b. Test Matrix Runs (continued)

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			515	770	1030	
CLOSED	12	+5	96	—	100	107
		↓	368	372	376	107
		+10	97	—	101	108
	↓	↓	369	373	377	108
	13	0	378	382	386	5
		-5	379	383	387	252
		↓	391	390	—	252
		+5	380	384	388	107
	↓	+10	381	385	389	108
	14	0	281	285	289	5
		-5	282	286	290	252
		+5	283	287	291	107
	↓	+10	284	288	292	108
	15	0	293	297	301	5
		-5	294	298	302	252
		+5	295	299	303	107
	↓	+10	296	300	304	108
↓						

TABLE 7. (CONTINUED)

b. Test Matrix Runs (continued)

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			515	770	1030	
CLOSED	16	0	223	227	231	5
		-5	224	228	232	252
		+5	225	229	233	107
		+10	226	230	234	108
	17	0	235	239	243	5
			—	—	248	5
		-5	236	240	244	252
		+5	237	241	245	107
		+10	238	242	246	108
	18	0	269	273	277	5
		-5	270	274	278	252
		+5	271	275	279	107
		+10	272	276	280	108

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			515	662	770	
CLOSED	19	0	200	208	204	5
		-5	201	209	205	252
		+5	202	210	206	505
		+10	203	211	207	506

TABLE 7. (CONTINUED)

b. Test Matrix Runs (continued)

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			515	770	1030	
CLOSED	20	0	212	216	—	5
		↓	330	334	338	5
		-5	213	217	—	252
		↓	331	335	339	252
		+5	214	218	—	505
		↓	332	336	340	107
		+10	215	219	—	506
	↓	↓	333	337	341	108
	21	0	42	46	50	5
		-5	43	47	51	6
		+5	44	48	52	107
	↓	+10	45	49	53	108
	22	0	342	346	350	5
		-5	343	347	351	504
		+5	344	348	352	505
	↓	+10	345	349	353	506
	23	0	145	149	153	5
		↓	420	424	428	5
		-5	146	150	*154	6 / *504
		↓	421	425	429	504
↓	↓					

TABLE 7. (CONTINUED)

b. Test Matrix Runs (continued)

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			515	770	1030	
CLOSED	23	+5	147	151	*155	107 / *505
			—	—	158	505
		↓	422	426	430	505
		+10	148	152	*156	8 / *506
			—	—	157	506
	↓	↓	423	427	431	506
	24	0	133	137	141	5
		↓	432	436	440	5
		-5	134	138	142	6
		↓	433	437	441	504
		+5	135	139	143	107
		↓	434	438	442	505
		+10	136	140	144	108
	↓	↓	435	439	443	506
	25	0	159	163	167	5
		↓	456	460	464	5
		-5	160	164	168	504
		↓	457	461	—	252
		+5	161	165	169	107
		↓	458	462	—	107
		+10	162	166	170	108
↓	↓	↓	459	463	—	108

TABLE 7. (CONTINUED)

b. Test Matrix Runs (continued)

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA) 515	770	1030	BASRU
CLOSED	26	0	171	176	180	5
			175	484	488	5
			480	——	——	5
		-5	172	177	181	504
			——	——	184	504
			481	485	489	252
		+5	173	178	182	107
			——	——	185	107
			482	486	490	107
		+10	174	179	*183	108 / *506
			——	——	186	108
			483	487	491	108

FAIRING DOOR	RCS CONFIG	BETA	PC (PSIA) 515	662	770	1030	BASRU
CLOSED	27	0	187	195	191	——	5
			——	——	472	476	5
		-5	188	196	192	——	252
			469	——	473	477	252
		+5	189	197	193	——	505
			470	——	474	478	107
		+10	190	198	194	——	506
			471	——	475	479	108

TABLE 7. (CONTINUED)

b. Test Matrix Runs (continued)

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			515	770	1030	
OPEN	28	0	723	727	731	5
		-2	724	728	732	566
		+2	725	729	733	567
		+5	726	730	734	568
	29	0	807	811	815	5
		-2	808	812	816	550
		+2	809	813	817	551
		+5	810	814	818	552

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)				BASRU
			400	555	690	770	
OPEN	30	0	569	573	577	581	5
		-2	570	574	578	582	550
		+2	571	575	579	583	551
		+5	572	576	580	584	552

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			515	770	1030	
OPEN	31	0	553	557	561	5
		-2	554	558	562	550
		+2	555	559	563	551
		+5	556	560	564	552
	32	0	586	590	594	5
		-2	587	591	595	550
		+2	588	592	596	551
		+5	589	593	597	552

TABLE 7. (CONTINUED)

b. Test Matrix Runs (continued)

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)				BASRU
			400	555	670	770	
OPEN	33	0	598	602	606	610	5
		-2	599	603	607	611	550
		+2	600	604	608	612	551
		+5	601	605	609	613	552

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			515	770	850	
OPEN	34	0	771	775	779	5
		-2	772	776	780	550
		+2	773	777	781	551
		+5	774	778	782	552

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			515	770	1030	
OPEN	35	0	626	630	634	5
		-2	627	631	635	550
		+2	628	632	636	551
		+5	629	633	637	552

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			515	770	850	
OPEN	36	0	638	642	646	5
		-2	639	643	647	550
		+2	640	644	648	551
		+5	641	645	649	552

TABLE 7. (CONTINUED)

b. Test Matrix Runs (continued)

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			400	515	650	
OPEN	37	0	783	787	791	5
		-2	784	788	792	550
		+2	785	789	793	551
		+5	786	790	794	552

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			515	770	900	
OPEN	38	0	662	666	670	5
		-2	663	667	671	550
		+2	664	668	672	551
		+5	665	669	673	552

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			400	515	650	
OPEN	39	0	735	739	743	5
		-2	736	740	744	550
		+2	737	741	745	551
		+5	738	742	746	552

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			400	515	770	
OPEN	40	0	747	751	755	5
		-2	748	752	756	550
		+2	749	753	757	551
		+5	750	754	758	552

TABLE 7. (CONTINUED)

b. Test Matrix Runs (continued)

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			515	770	1030	
OPEN	41	0	674	678	682	5
		-2	675	679	683	550
		+2	676	680	684	551
		+5	677	681	685	552
	42	0	687	691	695	5
		-2	688	692	696	550
		+2	689	693	697	551
		+5	690	694	698	552

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			515	770	850	
OPEN	43	0	759	763	767	5
		-2	760	764	768	550
		+2	761	765	769	551
		+5	762	766	770	552

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			515	770	1030	
OPEN	44	0	711	715	719	5
		-2	712	716	720	566
		+2	713	717	721	567
		+5	714	718	722	568
	45	0	699	703	707	5
		-2	700	704	708	566
		+2	701	705	709	567
		+5	702	706	710	568

TABLE 7. (CONTINUED)

b. Test Matrix Runs (continued)

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			515	770	1030	
OPEN	49	0	795	799	803	5
		-2	796	800	804	566
		+2	797	801	805	567
		+5	798	802	806	568
	50	0	650	654	658	5
		-2	651	655	659	550
		+2	652	656	660	551
		+5	653	657	661	552
	51	0	614	618	622	5
		-2	615	619	623	550
		+2	616	620	624	551
		+5	617	621	625	552
	60	0	861	862	863	538
	61	0	864	865	866	538

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)				BASRU
			99	250	500	900	
OPEN	140	0	37	38	39	—	5
			—	41	—	40	5

TABLE 7. (CONCLUDED)

b. Test Matrix Runs (concluded)

UMBILICAL DOORS	RCS CONFIG	BETA	PC (PSIA)			BASRU
			515	770	1030	
OPEN	49	0	539	540	541	538
		↓	—	—	854	539
		-2	828	829	830	820
		+2	834	835	836	833
		+5	850	851	852	843
	50	0	542	543	544	538
		-2	824	825	826	820
		↓	827	—	—	820
		+2	837	838	839	833
		+5	847	848	849	843
	51	0	545	546	547	538
		-2	821	822	823	820
		+2	840	841	842	833
		+5	844	845	846	843
	60	0	855	856	857	538
	61	0	858	859	860	538

NOTE: MATED CONFIGURATION

TABLE 8. RCS THRUST TARE CONSTANTS

a. Runs 1-101

Config.	KT1 (10^{-3}lbf/psia)	KT2 (10^{-3}in/lbf-psia)	KT3 (10^{-3}lbf/psia)	KT4 (10^{-3}in-lbf/psia)	KT5 (10^{-3}in-lbf/psia)
3	9.280	-54.570	-0.265	1.090	0.018
9	13.812	-11.287	-1.966	34.353	-4.071
10	5.706	34.513	-0.225	26.077	9.654
11	5.897	34.355	-0.746	28.742	4.047
12	5.827	34.504	-2.842	38.630	-12.276
21	4.663	-27.530	1.454	-7.093	8.011
140	0.081	-1.048	3.303	-18.700	3.702

TABLE 8. (CONTINUED)

b. Runs 103 - 866

Config.	KT1 (10^{-3}lbf/psia)	KT2 (10^{-3}in/lbf-psia)	KT3 (10^{-3}lbf/psia)	KT4 (10^{-3}in-lbf/psia)	KT5 (10^{-3}in-lbf/psia)
1	1.365	-8.928	0.955	-4.521	8.136
2	1.174	-8.770	1.477	-7.186	13.743
4	14.093	-9.290	-0.695	-1.970	-0.226
5	5.987	36.510	1.047	-10.246	13.499
6	6.178	36.352	0.525	-7.581	7.892
7, 49	4.813	45.280	-0.430	-3.060	-0.244
8	4.716	44.853	-1.973	31.273	-4.219
9	13.996	-9.717	-2.238	32.363	-4.201
10	5.890	36.083	-0.496	24.087	9.524
11	6.081	35.925	-1.018	26.752	3.917
12	6.011	36.074	-3.114	36.640	-12.406
13	6.108	35.066	-3.689	39.402	-17.628
14	1.295	-10.214	-3.259	42.462	-17.384
15	1.198	-9.206	-2.684	39.700	-12.162
16	2.782	-18.785	-0.083	27.244	6.911

TABLE 8. (CONTINUED)

b. Runs 103-866 (continued)

Config.	KT1 (10-3lbf/psia)	KT2 (10-3in/lbf-psia)	KT3 (10-3lbf/psia)	KT4 (10-3in-lbf/psia)	KT5 (10-3in-lbf/psia)
17	1.077	-9.197	-0.067	27.147	9.768
18	9.183	-54.997	-1.808	35.423	-3.957
19	9.319	-54.641	-5.227	29.530	-5.334
20	4.702	-27.601	-3.508	21.347	2.659
22	4.654	-28.868	6.423	-35.856	13.639
23	9.467	16.412	5.993	-38.916	13.395
24	9.476	17.750	1.024	-10.153	7.767
25	9.515	17.679	-3.938	18.287	2.415
26	4.852	45.209	-5.392	25.380	-5.596
27	14.132	-9.361	-5.657	26.470	-5.578
28	1.131	-9.487	1.475	-7.139	8.026
30	-0.058	-0.196	-1.591	57.980	-5.735
31	-0.181	-0.231	1.698	38.850	-2.202
32	9.099	-54.801	1.433	39.940	-2.184
33	9.222	-54.766	-1.856	59.070	-5.717

TABLE 8. (CONCLUDED)

b. Runs 103-866 (concluded)

Config.	KT1 (10^{-3}lbf/psia)	KT2 (10^{-3}in/lbf-psia)	KT3 (10^{-3}lbf/psia)	KT4 (10^{-3}in-lbf/psia)	KT5 (10^{-3}in-lbf/psia)
34	1.073	-9.683	-0.116	50.841	2.291
35	0.950	-9.718	3.173	31.711	5.824
36	0.904	-9.228	.000	46.987	-10.180
37	1.027	-9.193	-3.289	66.117	-13.713
38	-0.785	73.115	-0.432	43.694	-10.036
39	-0.662	73.150	-3.721	62.824	-13.569
40	-5.279	100.190	-2.002	54.641	-5.576
41	-5.402	100.155	1.287	35.511	-2.043
42	-0.739	72.625	2.741	28.418	5.968
43	-0.616	72.660	-0.548	47.548	2.435
44	-0.558	72.856	1.043	-10.432	8.170
45	-5.221	100.386	-0.411	-3.339	0.159
50	4.716	45.155	2.941	26.480	-0.627
51	-0.097	-0.125	3.371	29.540	-0.383
60	11.8	-30.53	-0.2766	0.4572	0.02086
61	-0.05214	0.04571	0.158	25.37	-2.114

TABLE 9. RCS THRUSTER PARAMETERS

Thruster No.	$K_{th_i} \times 10^3$	$K_{m_i} \times 10^3$
113	1.8023	0.6085
116	1.7398	0.5891
123	1.7731	0.5976
126	1.7596	0.5936
133	1.7504	0.6091
136	1.7217	0.5858
143	1.9428	0.6493
146	1.7952	0.6094
215	1.7106	0.5735
223	1.7278	0.5835
225	1.7237	0.5866
226	1.7539	0.5988
233	1.7610	0.5974
236	1.7529	0.5985
243	1.7912	0.6052
245	1.7298	0.5866
246	1.7418	0.5972
315	1.7177	0.5811
324	1.7348	0.5835
325	1.7298	0.5863
326	1.7066	0.5781
334	1.7398	0.5900
336	1.7398	0.5923
344	1.7459	0.5860
345	1.7801	0.6029
346	1.7569	0.5954

CALSPAN CORPORATION
AEDC DIVISION
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
NASA/RI ORBITER/TANK
PAGE 1

DATE COMPUTED 1-FEB-88
TIME COMPUTED 15:10:11
DATE RECORDED 25-NOV-87
TIME RECORDED 18:35:20
PROJECT NUMBER C185VB

RUN	CODE	M	PT	TT	Q	P	T	RE	RHO	A	REF LENGTHS(CLM,CLN,CLL)		
156	1	5.96	40.32	850.7	0.662	0.027	105.0	0.754E+06	0.213E-04	60.525	16.129	16.129	16.129

CONFIG	PTS	MSYS	WG	MDOT	PREF	TDP
23	1029.8	2	0.265	0.261	0.001	-103.9

---TUNNEL CONDITIONS---

- UMBILICAL DOORS CLOSED -

PN	ALPI	PHII	ALPHA	BETA	PTS	PT	TT	Q	P	PB01	PB02	PTANK1	PTANK2
* 1	-13.47	-48.59	-5.01	10.20	1029.8	40.3	850.7	0.662	0.027	0.108	0.047	0.158	0.138
2	-3.96	0.00	0.04	0.13	1029.6	40.4	850.7	0.664	0.027	0.113	0.053	0.165	0.146

SAMPLE 1. TABULATED DATA

RUN 156

CALSPAN CORPORATION
AEDC DIVISION
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
NASA/RI ORBITER/TANK
PAGE 2

DATE COMPUTED 1-FEB-88
TIME COMPUTED 15:10:11
DATE RECORDED 25-NOV-87
TIME RECORDED 18:35:20
PROJECT NUMBER C165VB

RUN	CODE	M	PT	TT	Q	P	T	RE	RHO	A	REF LENGTHS(CLM,CLN,CLL)		
156	1	5.96	40.32	850.7	0.662	0.027	105.0	0.754E+06	0.212E-04	60.525	16.129	16.129	16.129

CONFIG	MSYS	MPREV	TOLER	EZERO1	KM1	KM2	K1	K2
23	2	0.268	0.009	2.780	0.00238	0.00357	0.99782	0.99782

- UMBILICAL DOORS CLOSED -

---MASS FLOW DATA---

---VENTURI---

PN	PTS	PS1	PC1	PC2	TC	PTV2	DPV2	TTV2	PHIM	MDOTP	CD	WG	MDOT	DELMDOT	TGFLOW	TMODEL
* 1	1029.8	1030.3	1027.6	1027.6	532.0	1087.6	11.78	530.0	0.1035	0.2629	0.9915	0.265	0.261	-0.005	0.255	71.0
2	1029.6	1030.1	1027.4	1027.4	532.0	1087.5	11.88	530.0	0.1039	0.2640	0.9915	0.265	0.262	-0.003	0.255	71.0

ORIGINAL PAGE IS
OF POOR QUALITY

SAMPLE 1. (CONTINUED)

RUN 156

CALSPAN CORPORATION
AEDC DIVISION
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
NASA/RI ORBITER/TANK
PAGE 3

DATE COMPUTED 1-FEB-88
TIME COMPUTED 15:10:12
DATE RECORDED 25-NOV-87
TIME RECORDED 18:35:20
PROJECT NUMBER C185VB

RUN	CODE	M	PT	TT	Q	P	T	RE	RHO	A	REF LENGTHS(CLM,CLN,CLL)		
156	1	5.96	40.32	850.7	0.662	0.027	105.0	0.754E+06	0.212E-04	60.525	16.129	16.129	16.129

CONFIG
23

- UMBILICAL DOORS CLOSED -

---BODY AXES LOADS---

KT1	KT2	KT3	KT4	KT5
0.00947	0.01641	0.00599	-0.03892	0.01340

** ORBITER ** ** THRUST INCLUDED ** ** THRUST REMOVED **

PN	ALPI	PHII	ALPHA	BETA	PC	FN	MY	FY	MZ	MX	FNR	MYR	FYR	MZR	MXR	TBF	TBA	TSTING
* 1	-13.47	-48.59	-5.01	10.20	1027.6	3.82	16.41	2.34	-40.68	11.33	-5.91	-0.45	-3.82	-0.68	-2.44	71.0	68.9	72.0
2	-3.96	0.00	0.04	0.13	1027.4	6.93	19.63	7.48	-43.86	11.72	-2.80	2.77	1.32	-3.90	-2.04	71.0	69.0	72.0

ORIGINAL PAGE IS
OF POOR QUALITY

SAMPLE 1. (CONTINUED)

RUN 156

CALSPAN CORPORATION
AEDC DIVISION
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
NASA/RI ORBITER/TANK
PAGE 4

DATE COMPUTED 1-FEB-88
TIME COMPUTED 15:10:12
DATE RECORDED 25-NOV-87
TIME RECORDED 18:35:20
PROJECT NUMBER C185VB

RUN	CODE	M	PT	TT	Q	P	T	RE	RHO	A	REF LENGTHS(CLM,CLN,CLL)		
156	1	5.96	40.32	850.7	0.662	0.027	105.0	0.754E+06	0.212E-04	60.525	16.129	16.129	16.129

CONFIG
23

- UMBILICAL DOORS CLOSED -

---BODY AXES COEFFICIENTS---

	** ORBITER **			** THRUST INCLUDED **						** THRUST REMOVED **			
PN	ALPHA	BETA	PTS	CN	CLM	CY	CLN	CLL	CNR	CLMR	CYR	CLNR	CLLR
* 1	-5.01	10.20	1029.8	0.0952	0.0254	0.0584	-0.0629	0.0175	-0.1476	-0.0007	-0.0953	-0.0011	-0.0038
2	0.04	0.13	1029.6	0.1725	0.0303	0.1861	-0.0677	0.0181	-0.0697	0.0043	0.0329	-0.0060	-0.0032

SAMPLE 1. (CONTINUED)

RUN 156

CALSPAN CORPORATION
AEDC DIVISION
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
NASA/RI ORBITER/TANK
PAGE 5

DATE COMPUTED 1-FEB-88
TIME COMPUTED 15:10:13
DATE RECORDED 25-NOV-87
TIME RECORDED 18:35:20
PROJECT NUMBER C165VB

RUN	CODE	M	PT	TT	Q	P	T	RE	RHO	A	REF LENGTHS(CLM,CLN,CLL)		
156	1	5.96	40.32	850.7	0.662	0.027	105.0	0.754E+06	0.212E-04	60.525	16.129	16.129	16.129

CONFIG
23

- UMBILICAL DOORS CLOSED -

---BODY AXES COEFFICIENTS ABOUT "MATED COAST" REFERENCE CENTER---

	** ORBITER **			** THRUST INCLUDED **			** THRUST REMOVED **		
PN	ALPHA	BETA	PTS	CLMMC	CLNMC	CLLMC	CLMRMC	CLNRMC	CLLRMC
* 1	-5.01	10.20	1029.8	0.0324	-0.0586	0.0219	0.0063	0.0033	0.0006
2	0.04	0.13	1029.6	0.0431	-0.0540	0.0321	0.0170	0.0077	0.0109

SAMPLE 1. (CONTINUED)

RUN 156

CALSPAN CORPORATION
AEDC DIVISION
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
NASA/RI ORBITER/TANK
PAGE 5A

DATE COMPUTED 1-FEB-88
TIME COMPUTED 15:10:14
DATE RECORDED 25-NOV-87
TIME RECORDED 18:35:20
PROJECT NUMBER C185VB

RUN	CODE	M	PT	TT	Q	P	T	RE	RHO	A	REF LENGTHS(CLM,CLN,CLL)		
156	1	5.96	40.32	850.7	0.662	0.027	105.0	0.754E+06	0.212E-04	60.525	16.129	16.129	16.129

CONFIG
23

* BALANCE REFERANCE COMPONENTS *

PN	FN11	MY11	FY11	MZ11	MX11
* 1	-12.4137	0.0543	-15.6986	-59.7614	14.2446
2	-17.7951	-6.3702	7.4496	-43.9973	11.8869

SAMPLE 1. (CONTINUED)

RUN 156

DATE COMPUTED 1-FEB-88
TIME COMPUTED 15:10:15
DATE RECORDED 25-NOV-87
TIME RECORDED 18:35:20
PROJECT NUMBER C185VB

RUN	CODE	M	PT	TT	Q	P	T	RE	RHO	A	REF LENGTHS(CLM,CLN,CLL)		
156	1	5.96	40.32	850.7	0.662	0.027	105.0	0.754E+06	0.212E-04	60.525	16.129	16.129	16.129

CONFIG	PTS
23	1029.8

- UMBILICAL DOORS CLOSED -

---INCREMENTAL COEFFICIENTS---

** ORBITER DATA-BASELINE RUN = 506 **

PN	ALPI	PHII	ALPHA	BETA	ICNR	ICLMR	ICYR	ICLNR	ICLLR	PTS
* 1	-13.47	-48.59	-5.01	10.20	0.0036	0.0153	0.0636	0.0007	-0.0049	1029.8
2	-3.96	0.00	0.04	0.13	-0.0126	0.0171	0.1725	-0.0025	-0.0019	1029.8

SAMPLE 1. (CONTINUED)

RUN 156

CALSPAN CORPORATION
AEDC DIVISION
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
NASA/RI ORBITER/TANK
PAGE 9

DATE COMPUTED 1-FEB-88
TIME COMPUTED 15:10:23
DATE RECORDED 25-NOV-87
TIME RECORDED 18:35:20
PROJECT NUMBER C185VB

RUN	CODE	M	PT	TT	Q	P	T	RE	RHO	A	REF LENGTHS(CLM,CLN,CLL)		
156	1	5.96	40.32	850.7	0.662	0.027	105.0	0.754E+06	0.212E-04	60.525	16.129	16.129	16.129

CONFIG	PTS
23	1029.8

- UMBILICAL DOORS CLOSED -

---MOMENTUM RATIOS---

PN	T116T	T116A	MR116T	MR116A	T123T	T123A	MR123T	MR123A	T246T	T246A	MR246T	MR246A	PC1	PC2
* 1	2.0089	1.7874	3.4680	3.0855	2.0089	1.8216	3.4680	3.1446	2.0089	1.7694	3.4680	3.0891	1027.6	1027.6
2	2.0086	1.7870	3.4674	3.0850	2.0086	1.8213	3.4674	3.1440	2.0086	1.7691	3.4674	3.0885	1027.4	1027.4

RUN 156

SAMPLE 1. (CONCLUDED)